TELEVISION
UP - TO - DATE

Courtesy of the B.B.C.

HIGH DEFINITION TELEVISION.

Scene from the new opera, "Mr. Pickwick," produced by D. Bower at the Alexandra Palace. The televising is by the Marconi E.M.I. Emitron Cameras—an all-electric method, *i.e.* with no mechanically moving parts.

TELEVISION

UP-TO-DATE

BY

ROBERT W. HUTCHINSON, M.Sc.

Author of "Advanced Textbook of Electricity and Magnetism"
"Intermediate Textbook of Electricity and Magnetism"
"Elementary Electricity and Magnetism"
'Wireless Its Principles and Practice,'' "Easy Lessons in Wireless'
Joint Author of "Technical Electricity," etc

Formerly Revising Examiner in Electricity and Electrical
Engineering, Union of Educational Institutions

Late Principal, Municipal Technical College, Smethwick

LONDON

UNIVERSITY TUTORIAL PRESS LD.

Clifton House, Euston Road, N.W.1

Published December, 1935
Second Edition, April, 1937
Reprinted 194[illegible]

PRINTED IN GREAT BRITAIN BY UNIVERSITY TUTORIAL PRESS LD., FOXTON
NEAR CAMBRIDGE

PREFACE TO THE FIRST EDITION

NUMEROUS requests have been received during the last few months for a revised edition of my book on *Television* published some five years ago. I felt, however, that in view of the tremendous advances which television has made since that date, and of the fact that it is about to become an important public service, a mere revision as ordinarily understood would definitely not meet the case. It was therefore decided to produce a new, up-to-date book. In doing this I have followed the same fundamental idea in the method of treatment as I did with my book on *Wireless*—a treatment which a long experience showed me to be essential—a treatment which has met with the whole-hearted approval of the Press, and has been appreciated alike by teachers, students, experimenters, and the general reader.

The "man-in-the-street" has found it extremely difficult to acquire any clear notion, even during the last twelve months of television activity, as to the exact position of television. "Television is here": "Television is a long way off": "A television service ready to-morrow": "Television in three years": and so on, were the head-lines he encountered day by day in his newspapers, and a regrettable, faulty, "crazy-pavement" kind of impression was created in his mind which is yet far from being straightened out.

But, after all, television is no exception in this respect. Whenever a new science or a new branch of a science has been about to pass from the domain of the scientist into

daily and "commercial" life it has always, for a time, had to cope with the over-statements of its friends and the exaggerated belittleings of its foes—and to suffer from both. On the one hand a too zealous optimism has often portrayed possible future developments in language conveying the sense of present achievement or, at least, the threshold of achievement: on the other hand there has always lurked in some quarters a bitter jealousy, an almost hysterical fear that it will enter into too serious a competition with some existing interests. Both attitudes are unfortunate and there is really no necessity for either in this present case of television.

Again, in this case, and due entirely to a misconception of the principles involved, a fear still seems to be entertained in some quarters that television will interfere with the present highly successful sound broadcasting: but this is altogether wrong. Television uses for its transmission the *ultra-short* waves of the aether, whilst the present sound broadcasting uses the *long*, *medium*, and *short* waves.

Let me say at once that television—successful television—*is* here, and it has come to stay, and I am not merely scientifically optimistic nor is my statement exaggerated: I speak from personal experience, intimate association, and first-hand information. A television service to-day *can definitely* provide excellent and interesting entertainment in the home, and its development possibilities in the way of entertainment on the larger scale, education, commerce, etc., are great. What is wanted is *a television service available for all*—and that is about to start on its way. And from years of close touch with manufacturers I have sufficient faith in them to think that they can be trusted, in due course, to bring the reception *within the monetary reach of all.*

There is therefore a real need at this stage for an unbiased account of what television is, what it can do to-day, how it does it, and what its possibilities are for to-morrow. And I have tried to do this in the present book in a simple and interesting way, assuming no previous knowledge of electricity or radio or television on the part of the reader, yet basing all explanations on sound and *modern* scientific principles. The beginner can really "begin at the beginning," and acquire an intelligent and correct grasp of this fascinating subject.

The book is intended for beginners, for experimenters, for the members of Wireless and Television Clubs and Societies, for Schools, for students in Evening Continuation and Technical Classes, and for the general reader. Now nothing is more disappointing and disheartening to a reader than to be for ever encountering, in the explanations given in a book, terms and ideas with which he is totally unacquainted: hence whilst, as already stated, no previous knowledge of electricity or radio is assumed, a brief but sufficient account of all the necessary theory and modern views is given in a simple, rational, and scientific way. This is associated with its television applications from the outset, so that the reader will see the necessity for it: and it is made simple and interesting so that he will have no difficulty in comprehending it.

My point of view is that of one who has had many years' teaching experience in all phases of pure and applied electrical science, and with students of all ages—Secondary, Day and Evening Technical, University—close association with radio development, and many years' experience with experimental wireless and with television. This will explain why some points are particularly emphasised and even repeated, why simple theory runs hand in hand with

practical television applications, why readers' difficulties are so often anticipated and explained, and why warning notes of "pit-falls" frequently appear. And throughout I have tried to present the facts of television as it is to-day in as homely and interesting—yet scientifically accurate—a way as is possible.

R. W. HUTCHINSON.

December, 1935.

NOTE TO THE SECOND EDITION

THE early demand for a second edition of this book, the decidedly favourable opinions which have appeared in both the technical and general Press, and the letters received from all classes of readers indicate that my aims, as outlined in the Preface to the first edition, have met with approval.

Advantage has been taken of the opportunity to further simplify a few sections, whilst new matter has been added on the use of hard valves in time-base generators, and the section on receivers has been partly re-written in order to bring it up to date. A new chapter has been added on the B.B.C. first high definition station at the Alexandra Palace and a few notes have been incorporated dealing with some recent items of interest to the beginner—the large screen, magnetic focusing, range of television waves, using a television receiver, etc. Some new diagrams and illustrations have been included.

My thanks are due to the British Broadcasting Corporation, the Baird Television Co., the Marconi E.M.I. Television Co., and A. C. Cossor Ltd. for the kind loan of blocks and photographs for certain illustrations: the respective sources are indicated on the illustrations.

R. W. HUTCHINSON.

April, 1937.

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ILLUSTRATIONS

The blocks for Figs. 34, 37, and 99, 113 were kindly supplied by The General Electric Co., Messrs. Television Instruments, and Messrs. A. C. Cossor, respectively. The remaining diagrams (with only one or two exceptions) were specially prepared for the book by Mr. L. D. Day (Enfield) from the author's drawings.

TELEVISION UP-TO-DATE

CHAPTER I

A FEW NECESSARY IDEAS ABOUT ELECTRICITY, OPTICS, AETHER (ETHER), AND AETHER WAVES

NOTHING is more disappointing and disheartening to a beginner in a new subject than to be for ever encountering, in the explanations given, terms and ideas with which he is totally unacquainted. He cannot possibly obtain an intelligent grasp of the principles and methods of his subject—he only gets a scrappy, hazy, faulty *impression* and makes no progress. Television is a complex subject: it penetrates the domains of electricity, optics, sound, mechanics, chemistry, radio, photography, and the cinema, and it utilises the technique of Hollywood and Elstree quite as much as that of Broadcasting House. However, for a proper " start off " a few **modern** ideas about electricity and light *must* be known, and these are explained—sometimes, perhaps, in a rather crude and elementary way—in the present chapter.

1. Positive and Negative Electric Charges

So far back as 600 B.C. the Greeks knew that pieces of amber when rubbed attracted light bodies, and it is from the Greek word *ëlektron* (amber) that our word " electricity " has come. Years later it was found that most substances did the same: glass rubbed with silk, sealing-wax with flannel, and vulcanite with fur show the effect very well. A substance showing this property was said to be *electrified*, to be *charged*, or to be in a *state of electrification*, and the agent which caused this was called *electricity*.

Further investigation showed that some electrified bodies attracted each other, whilst others repelled. Thus glass

rubbed with silk repelled glass rubbed with silk but attracted vulcanite rubbed with fur. Numerous experiments of this kind led to the conclusions that (1) there were two states of electrification, (2) bodies in similar states of electrification repelled, (3) bodies in unlike states of electrification attracted.

Having discovered these facts, the early investigators decided on names for these two electrifications. Partly for reasons you will see presently, they agreed to call the state of electrification shown by glass rubbed with silk **positive,** and to say that any body showing this electrification was *positively charged.* They further agreed to name the state of electrification shown by vulcanite rubbed with fur **negative,** and to say that any body showing this electrification was *negatively charged.* Hence we have (1) Positively charged bodies repel each other; (2) Negatively charged bodies repel each other; (3) A positively charged body and a negatively charged body attract.

Moreover it was found that when glass was rubbed with silk not only was the glass positively electrified but, at the same time, the silk was negatively electrified, and by an equal amount. This applied in all cases.

Note particularly that the names *positive* and *negative* were allotted more or less arbitrarily: they *agreed* to say the glass was positive and the vulcanite negative. In view of what modern work has proved, it would have been better if they had chosen the names the other way about.

The next step was to find some explanation of the above and other facts they had gathered together. Now in the old days when anything mysterious occurred it was the custom to put it down to the action of some "spirit" or "demon," or "black vapour," or unknown "fluid," etc. Thus one theory was that "electricity" was an imponderable fluid, and that every body in its normal or neutral condition contained its definite or stock-amount of this fluid: if a body contained more than its stock-amount,

i.e. had an *excess* of fluid, it was *positively* charged, and if it had a *deficit* of fluid, it was *negatively* charged. Thus when glass was rubbed with silk some of this fluid was supposed to pass from the silk to the glass so that the glass had an excess and was positive, and the silk had an equal deficit and was negative.

Fluid theories are now abandoned. Modern work shows that electricity is much more fundamental—that it is, in fact, the " elementary substance " of which everything is composed. In the next section we give a short account of one or two points about the modern idea.

2. Protons and Electrons

We know that every piece of matter can be divided into smaller pieces by suitable means. If you take a piece of an elementary substance—an *element*, as the Chemist calls it—say a sheet of copper—you can cut it into smaller and smaller pieces, and then you can grind the pieces into a fine powder. But even then you have not got down to the smallest particles of copper of which the sheet was made up. You cannot do so by any ordinary means. The ultimate, smallest part of which all copper is made up is called an **atom** of copper. Of course the chemist gives us a very exact definition of the atom, but we need not trouble about his definition here.

Incidentally, to be strictly accurate, the smallest particle of a substance which can exist free, *i.e.* lead a separate existence as that substance, is called a **molecule**: but a molecule is made up of atoms, and in the case of copper the molecule really contains only one atom: but this also is a detail we need not worry about.

All atoms are excessively small—it would take of the order a hundred million side by side to make an inch. Even a drop of water contains over a million million million atoms.

Now if you were gifted with such remarkable powers that you could see, and examine, the atom of copper,

what an extraordinary sight you would witness. You would find that it consisted of a nucleus—a ball at the centre—surrounded by a number of small particles in very rapid motion, spinning, and also travelling round the nucleus. The tiny particles in constant movement are what we call **electrons,** and they show the same electrification as a rod of vulcanite which has been rubbed with fur, i.e. *they are negative.* The central ball—the nucleus of the atom—has, on the whole, a *positive* charge due to the presence in it of positive particles, and we refer to these as **protons.** The total (free) positive charge at the nucleus due to its protons is equal to the total negative of all the electrons outside the nucleus.

Electrons have actually been forced out of all sorts of matter and carefully investigated, and in all cases they are identical. They are the lightest "things" known, their mass (*which is, in fact, purely electricity*) being always about $\frac{1}{2000}$ of the mass of a hydrogen atom, which is the lightest atom known. Moreover, each always shows the same amount of electricity: we cannot get a smaller amount or charge of electricity, and so the charge is sometimes spoken of as *a natural unit of electricity.* The positive charge of a proton is equal to the negative charge of an electron, but the mass of a proton is much greater than that of an electron: it is practically the same as that of a hydrogen atom.

Electrons are inconceivably small. It would take nearly sixteen million times a million of them in a row touching each other, to make an inch. Thus the atom is of the order a thousand million million times the very tiny electron.

Now *every substance that we know* has its atom made up in the same way as the atom of copper, *i.e.* in all cases the atom consists of a centre or nucleus which has *on the whole* a positive charge (due to protons in it) surrounded by tiny moving electrons which are negative, and it is merely the number and arrangement of the electrons in the atom which determine what the substance really is.

In books on Chemistry there is usually a table—the Periodic Table—of all the known elements (just over 90) arranged in the order of increasing weight of atom. As an illustration, if we take the first eight names given in this table (viz. hydrogen, helium, lithium, beryllium, boron, carbon, nitrogen, oxygen), an atom of hydrogen (the lightest atom) consists of one revolving negative electron outside the nucleus and a nucleus having an equal positive charge or proton, an atom of helium has two electrons outside the nucleus, and the latter has on the whole two equal free positive charges, lithium has three electrons and a nucleus with three equal free positive charges, beryllium has four, boron five, carbon six, nitrogen seven, oxygen eight, and so on up to the heaviest element, uranium, with

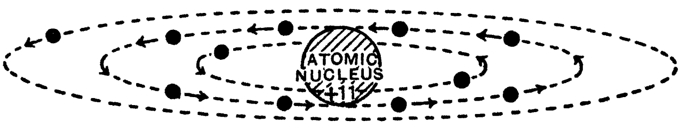


FIG. 1. Sodium Atom.

ninety-two. As a further illustration sodium has a nucleus with a *free* positive charge of 11, and it has 11 electrons outside: this atom is pictorially represented in Fig. 1.

But the marvellous thing is that when we get to rock-bottom, the atoms of all the elements merely consist of a positive nucleus (due to a number of protons in it which are positive), and a number of rapid-moving electrons outside the nucleus which are negative. Of course, most of the substances we come across are not elements and are not listed in the chemist's table: they are, however, built up of various elements, so that when we get down to the fundamentals of all materials we have the protons and very tiny electrons. All kinds of matter, then—*everything*—is made up of electricity (positive and negative) and nothing else. This conception—*the electrical structure of everything*—is of great importance in all modern scientific work.

We have said that the nucleus has *on the whole* a positive charge due to the protons in it: but there are electron charges in the nucleus also. Thus, taking the case of an atom of carbon (which, as stated above, has a nucleus with, *on the whole*, a charge + 6 and six electrons outside), the arrangement is really as shown in Fig. 2, *i.e.* the nucleus has a charge + 12, for it contains *twelve* protons, but there are also *six* electron charges each − 1, in the nucleus, so that the *free* positive charge is + 6, as stated, balancing the six electrons outside. Note that the chemist's atomic weight of carbon (taking hydrogen = 1) is 12.

The negative electrons are held within the atom by the force of attraction exerted on them by the positive nucleus. In various ways, however, one or more of the electrons outside the nucleus can be detached (temporarily) from the atom in which case the atom exhibits a positive charge since the free positive due to the protons at the nucleus now exceeds the negative of the electrons outside the nucleus. Similarly an atom may capture one or more electrons (temporarily) in which case the atom exhibits a negative charge. An atom which has lost an electron is spoken of as a **positive ion,** and one which has gained an electron as a **negative ion.**

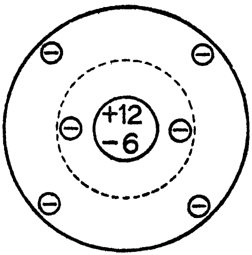


FIG. 2. Carbon Atom.

When glass is rubbed with silk some electrons pass from the glass atoms to the silk atoms, so that the glass has a deficit of electrons and is therefore positive, whilst the silk has an equal excess and is negative. When vulcanite is rubbed with fur electrons pass from the fur atoms to the vulcanite atoms, so that the vulcanite has an excess of electrons and is negative, whilst the fur has an equal deficit and is positive. The attraction between two oppositively charged bodies is due to the attraction

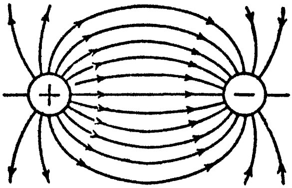


FIG. 3.

between the extra positive nucleus charge of the atoms of one body and the extra negative electrons of the other.

Incidentally, each electronic charge *in a nucleus* is joined up with a proton forming a **neutron** which has no charge since the positive and negative neutralise: but this is a detail at this stage.

3. Electric Fields and Electric Lines of Force

We have seen that an electrified body attracts or repels other electrified bodies. Now the space surrounding an electrified body where its influence is felt is called an **electric field.** If a small positive charge absolutely free to move were placed at any point in such a field, it would be urged by a definite force in a definite direction, and that direction can be indicated by what is called a **line of electric force** passing through the point in question. Thus Fig. 3 shows the lines of electric force in the electric field due to two metal balls with equal charges, the one positive and the other negative.

4. Electrical Potential or Electric Pressure

It is well known that water flows from a high water level to a low water level. Thus, if the two vessels of Fig. 4 contain water as indicated, then on opening the stop-cock water will flow from A to B, and the flow will continue until the two come to the same level. The actual quantity of water in B may be considerably greater than the quantity in A; *it is the difference in level which settles the direction in which the water will flow, not the quantity of water in the vessels.*

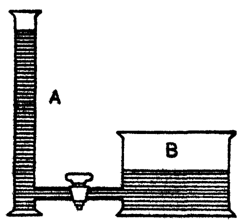


FIG. 4.

Similarly, heat flows from a body at a high temperature to a body at a lower temperature: and air flows from a place where the air pressure is high to a place where the air pressure is lower. In the first case it is the *difference in temperature* which settles the direction in which the heat flows. In the second case it is the *difference in air pressure* which settles the direction in which the air flows. Now in the study of electricity, *electric pressure* or *electrical potential* has much the same meaning as temperature, level, and pressure in the above cases: but a little "snag" arises here owing to the old fluid ideas conflicting with modern views.

Consider a positively-charged brass ball. We know that this has a deficit of electrons. If this be joined to the earth by a wire, we find it becomes neutral and we know the cause—electrons have come up from the earth to make up the deficit. But electricity *flowing* is an "electric current": hence we know that *a current has passed from the earth to the ball.* We will call this the **electronic current.** It is the *true* current, for it is the electrons (negative) which actually flow: the nucleus is more or less fixed in the atom.

But the early pioneers reasoned in this way. The positive ball, they said, has a surplus of electric fluid: when joined to earth this surplus electricity flows to earth, and it does so because the electric pressure (or potential) of the ball is higher than the electric pressure (or potential) of the earth. *The electric current,* they said, *flowed from the higher potential ball to the lower potential earth.* Further, the earth was taken as the zero of potential, and the ball was said to be at a positive potential. As this direction of flow is still spoken of we will call it the **conventional current** to distinguish it from the true electronic current which flows the other way, *i.e.* from what they had called the lower to the higher potential.

Again, if a negatively-charged ball, *i.e.* one with a surplus of electrons, be joined to the earth it also becomes neutral, and we know that this must be due to the surplus electrons

Courtesy of Baird Television Co

HIGH DEFINITION TELEVISION

A Spanish scene being enacted in one of the Baird Experimental Studios, the televising being by the Intermediate-Film System

passing to earth, i.e. *an electronic current has passed from the ball to the earth.*

But the early pioneers said this: The negative ball has a deficit of electric fluid: when joined to earth electricity flows from the earth to make up the deficit, and it does so because the electric pressure (or potential) of the ball is lower than the electric pressure (or potential) of the earth. *The electric current,* they said, *flowed from the higher potential earth to the lower potential ball,* and as the earth was taken as zero potential, the ball was said to be at a negative potential: this current we must again call the conventional current to distinguish it from the true electronic current which flows the other way, *i.e.* from ball to earth.

To summarise, then, we may say: The potential of a body is its electric pressure above or below that of the earth which is taken as the standard or zero: it is the electrical condition which settles the direction in which an electric current will flow. *A body* A *is at a higher potential or electric pressure than a body* B *if an electronic current tends to flow from* B *to* A, *and* A *and* B *are at the same potential if there is no flow between them.* And clearly the greater the potential difference (P.D.) the bigger will be the flow, *i.e.* the current.

Remember, then, that the old idea was that a positive charge was an excess of electric fluid or electricity, and that an electric current in a wire was a flow of this fluid, this positive charge, from higher to lower potential: this is still often used. The *true* current in a wire, however, is a flow of electrons (which are *negative*) from the lower to the higher potential.

We measure electric pressure or potential in terms of a unit called a **volt**: thus we speak of *an electric pressure of so many volts.*

5. The Continuous Electric Current

To fix ideas let us examine this question of an electric current a little more closely, taking the sort you are

probably most acquainted with, the **continuous current** (C.C.) or **direct current** (D.C.) always flowing in one direction which you get, say, from a battery.

The working of a battery is simply this: the internal action causes an excess of electrons to be piled up at what has been called the " negative pole " of the battery, and at the " positive pole " of the battery an excess of positive ions, *i.e.* atoms which have lost electrons: further, a " difference in electrical potential " is set up between the poles, the positive pole being at a higher potential than the negative pole.

Suppose then a copper wire with its end A joined to the positive pole, and its end B joined to the negative pole of the battery. Immediately an army of electrons sets off from B towards A, going in between the atoms and through the atoms, colliding with each other and with the electrons in the atoms, driving some of the latter out and taking their place. This hurrying, scurrying, bumping movement of electrons in the general direction B to A of the copper wire, *i.e.* from the negative pole to the positive pole of the battery, or from the lower to the higher potential, is the *electric current*, and the greater the number of electrons passing per second the greater is said to be the **current strength.** This is, of course, the true movement. It is still often said, however, that " the positive pole is at a higher potential than the negative pole, and this P.D. drives a current from the positive to the negative pole through the wire."

The strength of an electric current is measured in terms of a unit called the **ampere,** *i.e.* we speak of *a current strength of so many amperes.* A smaller unit is the *milli-ampere,* which is one-thousandth of an ampere.

Again, all this bumping, this wrenching-out of the electrons in the atoms, means that the current is encountering a certain opposition to its flow: this is spoken of as the **resistance** of the wire. Clearly the less the resistance the greater will be the current strength. The resistance of a

conductor is measured in terms of a unit called the **ohm**: thus we speak of *a resistance of so many ohms.* A smaller unit is the *microhm,* which is one-millionth of an ohm, and a larger unit is the *megohm,* which is one million ohms.

In passing we might just mention one more point. We have emphasised that *in metallic conductors, the electrons only are the "carriers" of electricity.* In certain liquids (electrolytes) both positive ions and negative ions move (in opposite directions). In gases, electrons and positive ions move (in opposite directions). We are mainly concerned at present, however, with currents in metallic conductors—wires and cables—and in these cases the movement is that of electrons only—the electronic current.

6. Magnetic Fields and Magnetic Lines of Force

Most people know what a magnet is, and that it has two poles called the north pole and south pole respectively. Further, it is well known that like poles repel and unlike poles attract.

The space outside a magnet where its influence is felt is called the **magnetic field** of the magnet. Now if a north pole could be placed at any point in a magnetic field it would be urged by a definite force in a definite direction, and this direction is indicated by what is called a **line of magnetic force** passing through the point in question. Fig. 5 shows the lines of magnetic force in the magnetic field due to two unlike poles facing each other. You can show the direction of these lines by placing the magnets under a sheet of cardboard and sprinkling iron filings on the cardboard: the filings will arrange themselves along the lines of magnetic force.

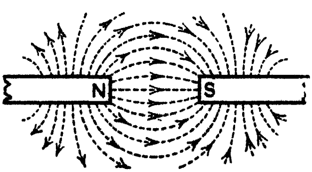


FIG. 5.

Now there is a very important connection between electricity and magnetism, and that is that *whenever an electric*

current flows along a wire a magnetic field is set up on all sides of it, the lines of magnetic force forming circles round about the wire, and when the current stops the magnetic field disappears. If you pass the wire vertically through a hole in a sheet of cardboard (Fig. 6), you can show the circular lines of force by means of iron filings. Fig. 7 shows the lines in the case of a current flowing in a long coil of wire. If you take an insulated copper wire and coil it round a bar of soft iron as shown in Fig. 8, then on starting a current in the wire the bar becomes a magnet, one end being a north pole and the other end a south: if the current goes in the opposite direction the bar will again be magnetised, but the polarity will be the other way about, viz. S on the left, N on the right.

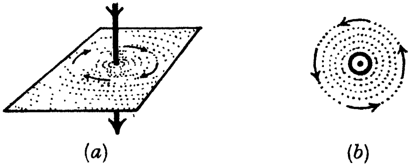


FIG. 6. Arrow on wire shows conventional current direction. We do this here because this old idea is still so often used: true current goes the other way.

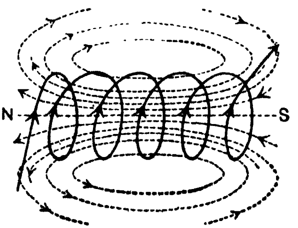


FIG. 7. Conventional current direction again indicated on wire.

7. Inductance and Capacity

In 1831 Faraday showed that if a magnetic field in the vicinity of an electric circuit was changed in any way an electric pressure—and in most cases a current—was set up in the circuit, such pressures and currents *only lasting for a moment while the change was taking place.* Pressures and

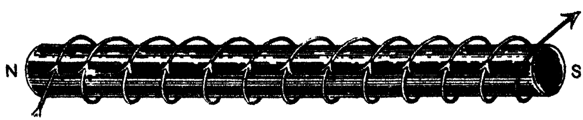


FIG. 8. Conventional current direction again indicated on wire.

currents produced in this way are called **induced pressures** and **induced currents.**

Thus when a current is started in a wire or its strength increased, there is a *momentary* induced pressure produced in the wire *in the opposite direction* which tends to choke the current back, opposes its growth. When a current in a wire is cut off or reduced in strength there is a *momentary* induced current set up *in the same direction*, which therefore opposes the cut-off or decrease and tends to prolong the current. Similarly when a current starts, stops, or changes in one circuit (referred to as the *primary* circuit) momentary induced currents are set up in any neighbouring circuit (called the *secondary* circuit).

The general name for this property shown by conductors is **inductance,** and it is measured in terms of a unit called the **henry,** *i.e.* we speak of *an inductance of so many henries.* In a straight wire the inductance is small: it is greater in a coil of many turns, and especially if the coil is wound on iron. It is clear that the inductance of a circuit will be an important factor if the current in the circuit is constantly varying in strength, or if it is an alternating current (Art. 8) which is constantly changing in strength and direction, for inductive effects always take place *during a change* and *oppose the change.* **Choke-coils, transformers,** and **tuning-coils** used in wireless and television work depend for their action on their inductance.

If we give a positive charge to a conductor—a brass ball, for example—we raise its potential. The more charge it takes to raise its potential by a given amount the greater we say is its **capacity** or **capacitance.**

Two metal plates placed parallel to each other a short distance apart with a very good insulator between them form what we call a **condenser.** The insulator is called the *dielectric*, and the two metals the *plates* or *coatings.* Two sheets of tin-foil pasted on opposite sides of a thin sheet of mica is a simple condenser.

Now let A and B (Fig. 9) be the two plates of a condenser, and let A and B be joined to a battery as shown. A becomes positively charged and B negatively charged, and the electrons on B and positive ions on A attract each other with an intense force. But from our point of view the important fact is that owing to the nearness of the positive ions on A the plate B gets more electrons on it than it would if A were not there; and similarly A has more ions than it would have if B were not there. The capacity of the arrangement is fairly big, and this has enabled us to collect big charges. The unit of capacity is called a **farad**, *i.e.* we speak of the *capacity of a condenser as being so many farads*. A *microfarad* is one-millionth of a farad. The larger the plates, the nearer they are together, and the better the dielectric, the bigger is the capacity of a condenser.

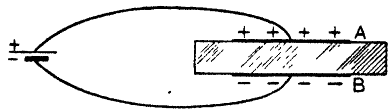


FIG. 9.

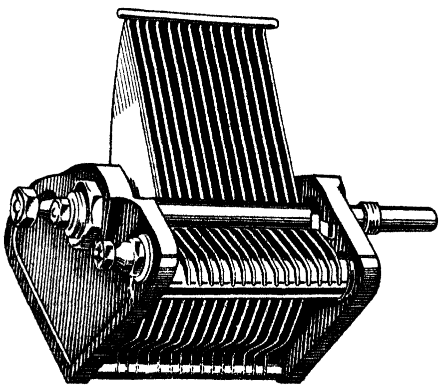


FIG. 10.

A variable condenser is one the capacity of which can be altered. The most common type employs an air dielectric, the variable capacity being obtained by rotating one set of metal plates into and out of another fixed set of metal plates, the rotating plates being all connected together and forming one coating of the condenser, the

fixed plates being similarly connected and forming the other coating of the condenser. Fig. 10 shows a typical variable condenser.

8. The Alternating Electric Current

The current from a battery flows continuously in one direction. There are, however, currents which do not flow in this way but regularly reverse, flowing for a certain time in one direction, then reversing, and flowing for the same time in the opposite direction; such are called **alternating currents** (A.C.).

Suppose alternating current is the supply to your house, and that you are again endowed with faculties which enable you to see what is going on in the cable. You would see, just as you saw with the continuous current of Art. 5, an army of electrons moving along, say towards your left, but the number of electrons flowing would get bigger and bigger until finally the increase in number stopped. Then the number of electrons in the flow would get smaller (although the movement would still be towards your left) and this decrease in number would continue until the flow to your left ceased.

Immediately, however, electrons would begin to flow along in the opposite direction, *i.e.* towards your right. Once again the number of electrons moving along would get bigger and bigger, until finally the increase in number stopped. Then the number of electrons in the flow would get smaller (although the movement would still be towards your right) and this decrease in number would continue until the flow to the right ceased altogether. Immediately, however, electrons would start off again in the first direction —towards your left—and the action would be repeated.

A complete surge in one direction, say to the left, is called an *oscillation*, and a double surge—to the left and back again to the right—is called a *vibration*. If you could have noticed the time which elapsed from the

moment when you had a maximum number of electrons in the flow towards, say, the left, to the moment when you had a maximum in the next flow towards the left, you would have found it to be about $\frac{1}{50}$ second. This $\frac{1}{50}$ second is called the *period* of the alternating current, and the number of such intervals in one second (50) is called the *frequency* of the current. Thus the frequency is 50 per second or, as it is usually worded, 50 *cycles per second.*

We might represent this alternating current by a curve such as is shown in Fig. 11. If the curve is above the line it means that the electrons are flowing in one direction—say to the left—and if the curve is below the line it means that they are flowing in the opposite direction—towards the right. The dots indicate the number of electrons in

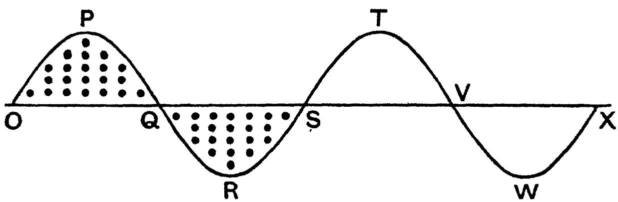


FIG. 11.

the flow (*i.e.* the strength of the current) although each dot means many electrons. Thus the current strength increases from zero at O to a maximum at P, then decreases to zero at Q: then the current comes on in the opposite direction, and the strength increases to a maximum at R, then decreases to zero at S, and so on. The time taken from the condition P to the condition T (or from O to S or Q to V) is the *period,* and the number of these times in one second is the *frequency.* We generally take the curve from O to S as representing a *cycle*: note that it includes an " up-loop " and a " down-loop."

The frequency in common use for lighting and power is 50 per second. When the frequency rises to the order of 100,000 per second the current is generally called a ***high***

frequency oscillatory current or a "high-frequency electric oscillation." In wireless, for example, we apply alternating current to the transmitting aerial in order that it may radiate energy which passes out into space in the form of waves—wireless waves—and for this to take place *very high frequency oscillatory current* is essential; in practice, this frequency may be of the order one million cycles or more per second: in television it may be sixty million cycles or more per second.

9. The Aether (or Ether). Waves in the Aether

Now we must leave our electricity and consider a most extraordinary, thin (shall we say "jelly-like"?) stuff which is really everywhere—inside us, in our bones and flesh, in atoms, in between atoms, in between molecules, in the air, everywhere outside us—although we cannot see it or feel it or smell it, or examine it in any way.

Early scientists supposed space (and matter) to be filled with a medium called the **aether** (or *ether*). This medium is invisible, practically weightless, elastic: it penetrates and fills all matter and all space: we move about in it but cannot feel it for it passes easily *through* our bones and flesh: the earth, the whole universe, is immersed in a limitless ocean of it.

We know that heat and light come to us from the sun and both travel millions of miles before they reach the atmosphere. We know also that heat and light come to us from the filaments of all electric lamps, yet many lamps are vacuum lamps, *i.e.* there is no air or gas inside—simply so-called empty space. Moreover, heat and light are both forms of energy, and in order to transfer energy from one place to another some medium was considered necessary: a medium conveying energy is always *strained* in doing so.

There must then be, it was said, beyond our atmosphere and in the lamp vacuum, some medium which can be strained. Further, many facts in seience demanded that this same medium must exist in our atmosphere and in all

Photograph: Courtesy of the B.B.C.

THE B.B.C. LATE LOW DEFINITION TELEVISION CONTROL ROOM.

On the right is the mirror-drum projection scanner, and to the left the two checking receivers. The engineers in position—right to left—are Projectionist, Vision-Control, Sound and Caption Control. The B.B.C. " tuning-in " design is seen in the transmitter (caption) drum in front.

forms of matter, as well as in so-called empty space. This all-pervading medium is the aether.

Now go back to the electric lines of Art. 3. What exactly are these lines? Suppose a positively-charged body is brought near a suspended negative body; the latter will begin to move when the other is still some distance away. Some force is moving it and, it was said, there must be a medium to convey the force. If we move a body by pulling it with a rope or by pushing it with a stick the rope or the stick is the medium connecting the force applied and the body moved: and the rope or the stick, in transmitting the force, is *strained*. Now in the case of the two charged bodies the experiment works if they are in a vacuum, so the medium is not air. It was said to be the aether, and the aether conveys the force because it is strained. We speak therefore of an **electric strain in the aether**, and the lines of Art. 3 really indicate the direction of the strain, and are often referred to as **electric strain lines in the aether.** Similar reasoning applies to the magnetic lines of Art. 6. The magnets and currents produce a **magnetic strain in the aether**, and the lines are really **magnetic strain lines in the aether.**

Incidentally, some scientists "ignore" aether and say it is just a *natural property of space* that it transmits these forces. However, it helps a beginner to imagine a medium —aether—so we will not argue about it here.

The names "wave," "wave motion," "wave-length," etc., are now household words. If a stone is dropped vertically into a smooth pond ripples or waves travel out in concentric circles, gradually spreading out until they reach the banks: this is an illustration of wave motion. A cork floating on the water bobs up and down with each wave but is not carried along: this means that the water itself does not travel along but is simply the medium by which the effect of the splash is transmitted. The energy of the falling stone is transmitted by these waves through

the water. Fig. 12 represents a wave motion of this type. The distance from crest to crest (B to F) or from trough to trough (D to H) is called the *wave-length*: it is really the distance the wave travels during one complete down and up movement or *vibration*. The distance the wave travels in one second is called the *velocity*: in water the wave velocity is evidently small.

Light also travels to us from the sun and from lamps, etc., by a wave motion. But light can travel through a vacuum, and as it is a form of energy the necessary medium for its transmission must be the aether. *Light waves, then, are waves in the aether.* The wave-length is very small, averaging about ·00006 centimetre, say $\frac{1}{50000}$ inch, and the velocity is very great, about 300,000,000 metres or 186,000 miles per second.

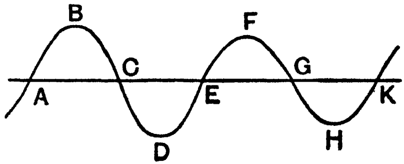


FIG. 12.

And there are other waves which travel through the aether. Some of these are of larger wave-length and some of smaller wave-length than light, but in all cases the *velocity* of the aether waves is the same, viz. 186,000 miles per second. Thus in wireless and television the very high frequency oscillatory current in the transmitting aerial "radiates" energy which travels out through the medium in the form of waves—the "wireless waves." These waves can be transmitted through a vacuum so the medium is aether. *Wireless waves, then, are waves in the aether,* and their velocity is 186,000 miles per second. Their wave-length, however, is much greater than the wave-length of light. In ordinary broadcasting the wave-lengths are from 200 to 600 *metres* and from 1100 to 1900 metres: in television aether waves of from 4 to 8 metres are used.

It is owing to the very great velocity of aether waves that if you are living, say, in Birmingham you can

hear " on the wireless " the strokes of Big Ben in London practically at the instant that it actually strikes. When Big Ben strikes *sound waves travel through the air* in all directions (sound waves will *not* pass through a vacuum—they are *not* aether waves), but the velocity is only about 1120 *feet* per second; and moreover after a comparatively short distance the energy is dissipated and the sound cannot be heard. Even if the *sound waves* did travel right up to Birmingham they would take about 10 minutes to get there. When heard " on the wireless " the sound has not travelled *as sound waves* all the way. In the transmitting station in London the sound is *changed* into a corresponding *electric current* and superimposed on the high frequency aerial oscillations which are producing the wireless waves: the signal is thus carried, as it were, by the wireless waves to Birmingham at a speed of 186,000 miles per second, *i.e.* practically instantaneously, and there your wireless set and loud speaker turn it back into sound.

X-rays, gamma rays from radium, and ultra-violet rays are wave motions in the aether of shorter wave-length than light, whilst radiant heat is of slightly bigger wave-length than light: but all have the same velocity.

AETHER WAVES AND APPROXIMATE WAVE-LENGTHS

(In order of increasing wave-lengths)

NAME	WAVE-LENGTH
Gamma rays	Small fraction of a millimetre
X-rays	About ·00000001 cm.
Ultra-violet rays	·00001—·00003 cm.
Light	·00004 (violet)—·00008 (red) cm.
Infra-red rays (heat)	·002—·03 cm.
Laboratory " wireless waves "	·008—15 cm.
Micro-waves	·15—1·5 m.
Television (ultra-short waves)	4—8 m.
Short wave wireless	10—130 m
Medium wave broadcasting	200—600 m.
Long wave broadcasting	1100—1900 m.
Other " wireless waves "	1900—10,000 m.

10. Reflection and Refraction of Light

A body which is itself "giving out light" is usually at a high temperature, and is called *self-luminous*, whilst bodies which do not are called *non-luminous*. We "see" a luminous body because of the light it is emitting: we see a non-luminous body because light is falling on it from some source of light and it is reflecting some from its surface.

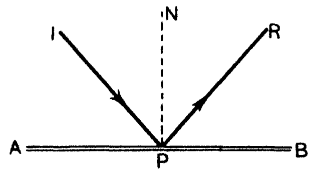


FIG. 13.

You often hear the expression that "light travels in straight lines." Of course we know that light is transmitted by waves in the aether, but the waves are so small (many thousands to an inch) that their path is, to all intents and purposes, straight. When we wish to show the path of light on a diagram we represent the direction in which the light is travelling by a straight line: this is called a *ray* of light. A number of such rays is a *beam* of light.

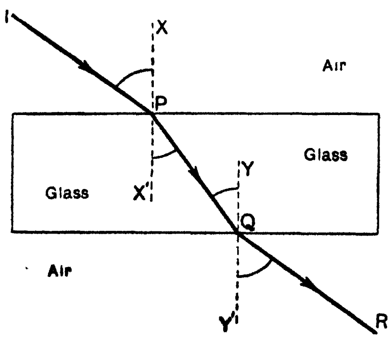
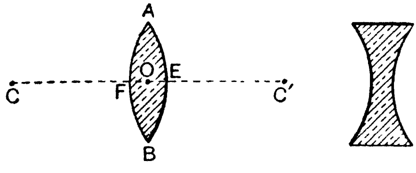


FIG. 14.

If a ray of light IP (Fig. 13) meets a highly polished metal surface AB it is turned back or **reflected** along PR so that the *angle of incidence* IPN is equal to the *angle of reflection* RPN. Evidently if the surface is not smooth an incident beam of light will be reflected rather irregularly.

Again consider a ray of light IP entering a block of glass (Fig. 14): it is bent or **refracted** at P and travels in the direction PQ, the *angle of refraction* X'PQ being *less*

than the angle of incidence in the air IPX. When PQ emerges at Q it is refracted again and travels along QR, the angle of refraction in the air, viz. RQY′, being *greater* than the angle of incidence in the glass PQY. Light is bent towards the perpendicular or normal when it enters a *denser* medium and away from it when it enters a *rarer* medium.



(*a*) (*b*)

FIG. 15.

11. The Action of a Lens

Every one is familiar with a lens. As a rule the two surfaces are either both portions of spherical surfaces or one is plane and the other spherical. It is usual to divide lenses into **convex lenses** and **concave lenses.** Fig. 15 (*a*) shows what is called a *double convex lens* and Fig. 15 (*b*) a *double concave lens.*

In Fig. 15 (*a*) C is the centre of the spherical surface AEB, and C′ is the centre of the spherical surface AFB. The central point O is called the *optical centre* of the lens, and COC′ its *principal axis.* A ray of light entering the lens is refracted where it enters and refracted where it comes out: its direction is therefore changed in going through the lens. It can be shown, however, that if the lens is a thin one (and they generally are) *any ray of light which happens to pass through the optical centre O goes straight on.*

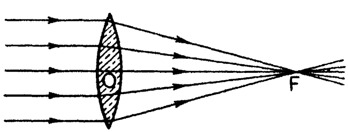


FIG. 16.

Experiment shows that if a parallel beam of light falls on a convex lens in a direction parallel to the principal axis all the rays converge to, or meet at, a point F on the principal axis and on the other side of the lens. This is shown in Fig. 16, where the parallel beam is shown coming

from the left. The point F is called the **principal focus,** and the distance OF is called the **focal length** of the lens.

Let us now consider the formation of an image of an object by a convex lens, and we will first consider the object to be a good distance from the lens—a distance much greater than the focal length. In Fig. 17 (*a*) let AB be the object, XX the principal axis, F the principal focus,

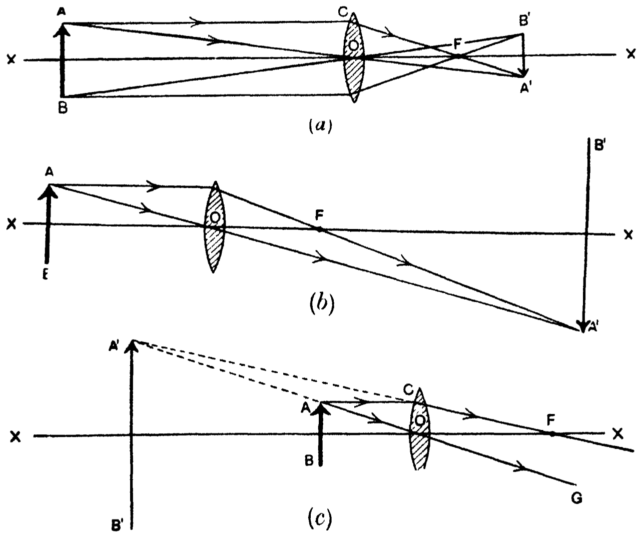


FIG. 17.

and O the optical centre of the lens. Now a ray AC from the point A of the object and parallel to XX is refracted by the lens so as to go through F, *i.e.* its path is CFA′. Again a ray AO from the same point A and going through O, passes straight on, *i.e.* its path is OA′. The point A′ where the two rays from A intersect gives the image of A. Similarly as shown in the figure, the image of B is formed at B′, and the same applies to all points of the object AB.

Thus A′B′ is the image of AB. Notice that in this case the image is *upside down* compared with the object and is *smaller*. Moreover, the rays forming the image *actually do pass through the points of the image*. This image formed by the lens is a *real* image, and if a screen were put at A′B′ the image would be formed on the screen.

Fig. 17 (*b*) shows the case where the object is much nearer the lens than in the last case, but still at a distance greater than the focal length. The image is again upside down, but it is *larger* than the object: again it is a real image, and can be obtained on a screen.

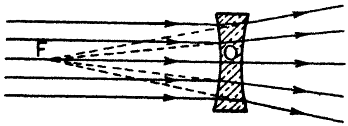


FIG. 18.

Fig. 17 (*c*) shows the case where the object is brought still closer to the lens, its distance being now less than the focal length. The ray AC is refracted through the focus F, whilst AO goes straight on. Now the lines CF and OG in the figure are going away from each other and must be produced backwards to meet at A′. In this case A′B′ is the image of AB. Notice the image is *erect*, not inverted, and is *larger* than the object. Moreover the rays do not actually intersect at A′, but only appear to do so: the image is called a *virtual* one (not *real*), is on the same side as the object, and it cannot be obtained on a screen.

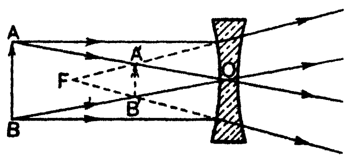


FIG. 19.

Turning now to the concave lens, if a parallel beam of light falls on it in a direction parallel to the principal axis all the rays *appear* to diverge from a point F on the *same side* of the lens. F is the principal focus in this case, and OF is the focal length of the lens. (Fig. 18.)

Fig. 19 shows the formation of the image A′B′ of the object AB (the rules for drawing it are the same as before).

It is *erect*, *less* than the object, *virtual*, and cannot be formed on a screen. This is always so with a concave lens, and we need not consider any further positions of the object.

12. The Human Eye and Persistence of Vision

The human eye acts on the same principle as that indicated in Fig. 17 (*a*). Near the front of the eye is a convex lens called the *crystalline lens* which corresponds to the double convex lens of Fig. 17 (*a*), and at the back of the eye is a sensitive screen called the *retina* on which the image of any external object is formed (the retina is therefore in the position A′B′ of Fig. 17 (*a*)). Muscles (called the *ciliary muscles*) attached to the eye are capable of altering the focal length of the lens by altering its curvature, so that although an object may be at various distances from the eye a distinct image is focused on the retina. The retina is covered by a close network of nerves that pass out of the eye as a sort of "main cable" called the *optic nerve* which conveys the impression to the brain.

The retina, however, is very complex in structure. It consists of about ten layers of tissue. The second layer from the surface contains some strange bodies called rods and cones: in the outer parts of the rods is a fluid called the visual purple. There is a part of the retina called the *fovea centralis* which is very rich in rods and cones, and is the most sensitive part of the retina. When we look at an object we move the eye-ball by the muscles controlling it so as to bring the image on to this most sensitive part. Note that the image on the retina is inverted, and one of the wonderful facts about vision is that the image impression sent along the optic nerve to the brain is interpreted so that we see the things the right way up. Note, too, that the retina really consists of an *enormous* number of sensitive parts each of which sends its own impression to the brain, *i.e.* the impression sent to the brain is not a simple addition of all the impressions into one resultant but a separate appreciation of each.

It may be said that television (and the cinema) depends upon a certain property of the human eye which we are almost unconscious of, namely, that any impression produced on the retina does not disappear immediately the object is taken away: the impression lasts for about one-sixteenth to one-tenth of a second. This property is called " persistence of vision."

There are many simple illustrations of this persistence of vision. Thus if a match with its end glowing be rapidly moved round in a circle we do not see a bright point changing its position, but a continuous circle of light. If a bird be drawn on one side of a piece of cardboard and a cage on the other side, and the card be rapidly rotated by strings fastened to two opposite edges of the card, the bird will be seen inside the cage: in this case we get, say, first the image of the cage on the retina and then before this impression has disappeared we get the image of the bird, and so on: hence the bird and cage are " seen " together. The film used at the cinema theatre is made up of a large number of small photographs each of which pictures a motion just slightly after the one in front of it. With these run through the projector at a rapid rate, say sixteen or more complete pictures per second (24 per second is usual), the appearance on the screen is that of continuous movement and not a jerky movement of still pictures one after the other.

Imagine we have a chess-board with black and white squares hung up on the wall in a dark room, and suppose that we have a lantern from which we can direct a narrow beam of light on the board—say a beam which just covers one square. Now imagine the beam moved slowly along one row of squares: we will see first a dark square, say, then a white one, then a dark one, and so on, *i.e.* one square at a time. Suppose now the beam moves along the row quickly, say in $\frac{1}{16}$ of a second: we would, by persistence of vision, see the whole row at one time. Imagine now that the beam could be made to traverse the whole board

in this way in $\frac{1}{16}$ of a second, and that it kept on doing it: we would see the whole board complete on account of our persistence of vision, although the light is only on one small area at any one instant.

Suppose your friend is standing against the wall and that the narrow beam of light is projected on her (his) face (Fig. 20). Suppose this light spot is moved quickly, say from right to left over the upper part of the head: then suppose it is moved quickly across again, but that this second journey is a little below the first one, the edge of this second spot-light journey just touching the edge of the first journey: then suppose a third journey is made across, displaced again a little below the second, the edge of this third spot-light journey just touching the edge of the second one, and so on.

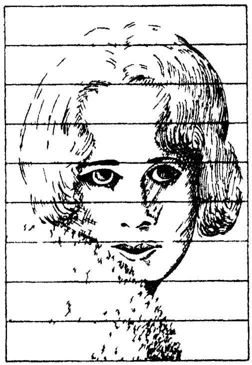


FIG 20

Finally, imagine these journeys to take place so rapidly that the whole face is covered in $\frac{1}{16}$ of a second, and that the operation is kept going on at the rate of 16 complete "scans" over the face per second: then the whole face would be visible by our persistence of vision, although the spot-light is only on one small area at any instant. As you will see presently this is what is done in television.

If you cover a screen with "luminous paint," throw a bright patch of light on the screen from a lantern, and then remove the light beam, the "image" will remain on the screen for a time, gradually fading away. It is possible that the visual purple in the rods of the eye acts in some way similar to this paint, and causes our persistence of vision.

CHAPTER II

THE RADIO LINK—BROADCASTING

RADIO and broadcasting are, of course, an essential part of television. It is impossible to give anything but a very brief outline of this branch of our subject in this book. For further details some good book on Wireless must be consulted.

1. Wireless

We have mentioned that at a wireless transmitting station very high-frequency alternating current—*high-frequency electrical oscillations*—are passed to the transmitting aerial: the frequency employed is of the order 1,000,000 cycles and more per second. Various methods have been used for the production of these, but most of them have given way to the use of valves: *valve transmitters* are mainly used in modern stations.

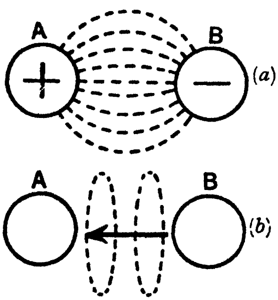


FIG. 21.

For the present, however, we will take as our starting point the fact that we have very high-frequency electrical oscillations—the very rapid surging of electrons to and fro—in the transmitting aerial. These would be represented by a curve like Fig. 11, but the "loops" would be much narrower: in Fig. 11 the condition in the space OS—an up loop and a down loop—takes $\frac{1}{50}$ second, but there would be about 20,000 of these double loops in $\frac{1}{50}$ second in the case of the aerial oscillations.

Look at Fig. 21. At (*a*) we have A positively charged and B negatively charged, the *electric* strain lines (page 7)

being as shown. Suppose now A and B become discharged by a spark passing across the gap. This spark is a current and the *magnetic* strain lines are as shown at (*b*). This sparking, in many cases, is oscillatory—a rush from B to A followed by a rush from A to B, and so on, the rushes getting weaker (in the case of a spark) until they die down. We have in fact a *high-frequency electrical oscillation*, so that we have rising and falling and reversing electric strains, and rising and falling and reversing magnetic strains in the aether, and the two sets of strains are at right angles to each other. And if we can arrange matters so that the charging and discharging of A and B can be kept going on, these rising and falling and reversing electric and magnetic aether strains at right angles to each other will keep going on.

Now going back to our transmitting aerial, the high frequency electrical oscillations in it give rise to electric and magnetic strains in the aether at right angles just as in the case above, and these strains are also constantly changing—varying periodically: unlike the spark case, however, the "rushes" do not get weaker and die down —the oscillations are *continuous* and keep on. And Maxwell showed, years before wireless came to the front, that if at any place we have electric and magnetic forces at right angles, and the two are rapidly changing—rising, falling, reversing, or varying periodically—we are bound to have an "electromagnetic disturbance" spreading out from that place in the form of a wave motion in the aether travelling with the same velocity as light. The oscillations in the transmitting aerial, therefore, radiate energy which travels out through the aether in all directions with the velocity of light, viz. 186,000 miles or 300,000,000 metres per second. These are the wireless waves.

In all forms of wave motion, the **wave-length** is the distance the wave travels during one complete vibration, and the **frequency** is the number of complete vibrations—

" to and fro " movements, double oscillations, or *cycles*—in one second: hence it follows that—

$$\text{Wave-length} \times \text{Frequency} = \text{Velocity.}$$

Every transmitting station is allotted a certain frequency (and therefore wave-length) for its transmissions and is *expected* to keep to it so as to avoid interfering with other stations. Thus the frequency for the London Regional is 877 kilocycles or 877,000 cycles, and therefore its wave-length is about 342·1 metres, for the frequency in *cycles per second* multiplied by the wave-length in *metres* gives the velocity of the wave in *metres per second*, viz. 300,000,000. Put another way, if you take from your newspaper the wave-length of any station *in metres* and its frequency in *kilocycles* (which is given instead of cycles) you will find the product of the two is about 300,000.

The *inductance* and *capacity* in the transmitting circuit play an important part in the wave-length and frequency of the wave the station sends out. If L denote the inductance and C the capacity it can be shown that—

$$\text{Wave-length is proportional to } \sqrt{LC}$$

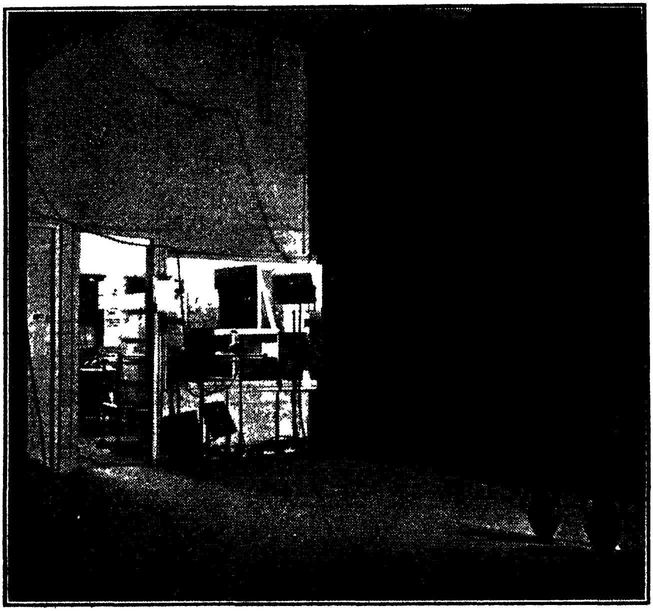
$$\text{Frequency is proportional to } \frac{1}{\sqrt{LC}}$$

so that increasing L or C increases the wave-length and reduces the frequency of the waves sent out.

Now when the waves from the transmitting station fall upon your receiving aerial they set up high frequency electrical oscillations in it, *i.e.* high frequency currents, corresponding to those at the transmitting end, your aerial, etc., being *tuned*, as we say, to the arriving waves. An aerial has a certain inductance and capacity, and in your receiver, but joined to the aerial, are " tuning coils " (inductance) and " condensers " (capacity), and you alter these (*i.e.* you alter $\sqrt{LC}$ of your receiving apparatus)

until your set responds to the wave you want. Increasing L or C tunes your set to respond to a longer wave.

This " tuning to resonance " is well known in work connected with all forms of wave motion. To illustrate



Photograph: Courtesy of the B.B.C.

THE B.B.C. LATE LOW DEFINITION TELEVISION STUDIO.

Photograph is taken looking towards the Control Room. The large black curtain screened the orchestra and their lights from the photo-electric cells. The cells are near the projector window, a further one being placed near the ceiling.

the idea, uncover the strings of a piano and sound a tuning-fork near them. You will notice that several of the strings are affected by the sound waves from the fork, but you will find that that particular string which has the same vibration-frequency as the fork will be affected most, and

it may be set so strongly in vibration that it gives out the same note as the fork. The first wave hits the piano string forward, say: the string comes back, and then just when it starts forward the second time, the second pulse from the fork just reaches it and hits it forward again, and so on; thus the vibrations of this string are increased. Another string that has not got the same frequency as the fork is hit forward (by a later pulse) when it is moving back and so it soon pulls up. It is similar with your tuned aerial and receiver. By altering L and C you really arrange matters that when a particular wave comes up and starts an oscillation in your aerial, that surge rushes along the aerial and comes back just in time to be caught by the next pulse reaching the aerial—just like the piano string being hit forward again at the right instant. In scientific language, you make the frequency of your receiving aerial system equal to the frequency of the arriving wave and so get resonance.

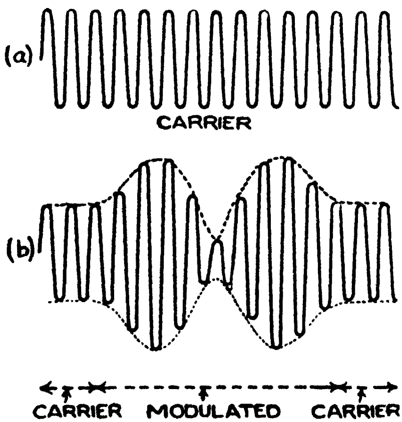


FIG. 22.

Now let us go back once more to the transmitting end. The continuous high-frequency electrical oscillations in the transmitting aerial produce a continuous wave in the aether which is passing out all the time broadcasting is taking place. This wave is called the **carrier wave** of that station and may be represented as at (*a*) in Fig. 22. That is the wave-length given in your newspaper.

Joined in various ways to the transmitting apparatus, and therefore indirectly to the transmitting aerial, is a

microphone. When the person broadcasting speaks into the microphone the sound waves cause changes in the microphone current, and therefore corresponding variations in the aerial current, so that we have a current in the transmitting aerial which varies in strength in a most complicated way according to the words spoken. This again in turn produces a complicated aether wave varying according to the words spoken which, when it reaches the receiving aerial, sets up corresponding complicated electrical oscillations in it, *i.e.* currents varying in strength in a complicated way according to the words spoken at the transmitting end. We say that the speech of the broadcaster **modulates** the carrier wave: this modulation of the carrier may be represented as at (*b*) in Fig. 22.

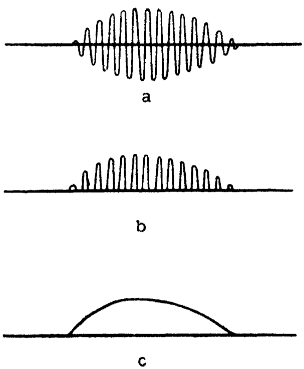


FIG. 23.

Now the actual oscillating currents we deal with in wireless are of much too high a frequency (a million or more per second) to work, say, a telephone directly, for the vibrating disc would not have time to move between one rush (sending it one way) and the next rush in the opposite direction (sending it the other way). Thus if a series of rapid oscillations like Fig. 23 (*a*) were passed to a telephone it would not respond. If, however, we wipe out the swings of the electrons in one direction —say the half "puffs" below the line—and allow only the other swings to pass, we will have in the telephones a varying current, but it will always be flowing in the same direction—it will be a ***rectified*** or ***unidirectional but varying*** current [Fig. 23 (*b*)]. The telephones will still be unable to respond to the separate puffs of this rectified current, but these may be looked upon as collected together to

form a *slowly varying one-direction current* as at (*c*), and to this the telephones will respond. In your receiver this rectification is done by a valve (the " detector valve ").

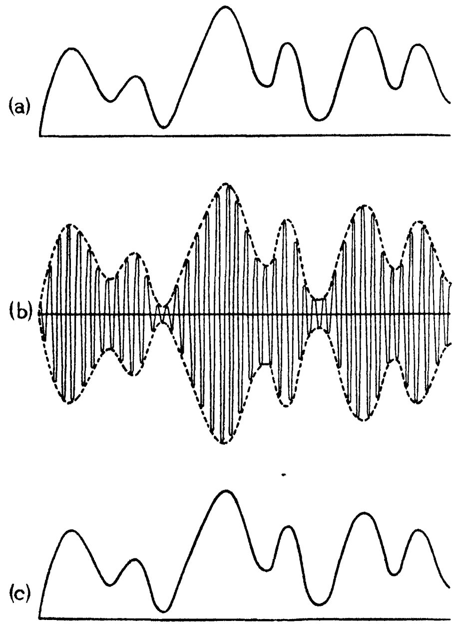


FIG. 24.

(a) Varying current produced in the microphone (by the voice of the broadcaster): this is passed to the high-frequency aerial oscillations which are producing the carrier wave. (b) The "modulation" caused by (*a*): the "modulated wave" on reaching the receiving aerial sets up oscillations corresponding to those at the transmitting aerial and these pass to the receiver for amplification and rectification. (c) The varying current passed finally to the loud speaker: the sound you get due to (*c*) is an exact copy (or should be) of the sound which caused (*a*).

Thus the complicated electrical oscillations in your receiving aerial pass on to your rectifying or detector valve or crystal which wipes out the puffs at one side leaving the complicated puffs at the other side to pass through. These latter unidirectional puffs, still complicated according to the words spoken, pass through the telephones or loud speaker which respond to the resulting slower variations and vibrate accordingly, and the words are reproduced. The curves in Fig. 24 will make the idea clearer: the telephones respond to (*c*).

Notice particularly that when the broadcaster speaks into the microphone he does not alter the frequency or the

wave-length of the carrier wave, but he does alter the *strength* of the oscillations, *i.e.* the number of electrons taking part in the different swings, and this strength variation depends on the words spoken. It is this strength variation corresponding to the peculiar irregular shaped curves of Figs. 22 (*b*), 24 (*b*) which, when one half has been wiped out by the detector or rectifier causes the discs of the telephones or the cone of the loud speaker to vibrate in the same way and produce the words.

The carrier wave "carries" the slower variations [Fig. 24 (*b*)] produced by the speech and the music through the aether almost as an aeroplane carries its pilot through the air. If the "high-frequency carrier" is not there you can shout as hard as you like into the microphone or sing the sweetest song, and the aether will have none of it: only the air will take the sound for a short distance.

Incidentally we may mention that at the sending end the microphone variations produced by the voice are usually strengthened or amplified before being combined with the aerial oscillations, *i.e.* with the oscillations producing the carrier wave. Similarly at the receiving end the aerial oscillations are frequently magnified or amplified before passing on to the detector valve, and the current variations are again amplified after the detector valve before being passed on to the loud speaker.

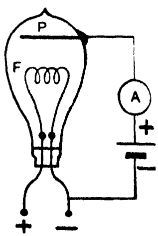


FIG. 25.

2. The Action of a Wireless Valve

One of the earliest valves was called the **diode**, and it is shown in Fig. 25. It consists of an ordinary **filament** electric lamp—the filament is marked F—fitted with a metal plate P which is called the **plate** or **anode**. The space inside is a vacuum (which, normally, is non-conducting).

When the filament is heated by passing a current through it from an accumulator joined to the points marked +

and –, the *very hot* filament gives off (negative) electrons, *i.e.* at this high temperature and in a vacuum, electrons are able to leave the metal filament altogether and go into the space outside it. Hence if P be kept positive by joining it to the positive pole of another battery, shown on the right, the negative electrons thrown off by F will be attracted towards the positive plate P. But electrons moving from F to P means, of course, that an electronic current is going from F to P, and so the indicating instrument A will be deflected. We call a current in this circuit a "plate current."

Now the ordinary valve used in wireless receivers to-day is known as a **triode.** It has a filament F and a plate P, but it also has a wire **grid** G between them (Fig. 26). Let the plate and filament be joined to a battery (from 30 to about 200 volts in ordinary cases of wireless receivers) so that electrons are passing from filament to plate. We are assuming that the filament is heated by an accumulator (not shown in Fig. 26). The battery shown is called the *high tension battery,* and the accumulator the *low tension.*

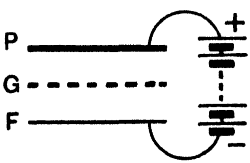


FIG. 26.

Imagine now that the grid G acquires from some outside source a negative potential. It will repel the electrons coming from the filament and stop many of them from reaching the plate; hence the plate current will decrease. If the potential of the grid becomes positive it will attract the electrons from F, and (as P is at a higher potential in practice), many continue their motion through the grid holes to the plate; thus the plate current will increase. To summarise—*lowering the grid potential reduces the plate current: raising the grid potential increases the plate current.* Thus by varying the potential of the grid we can vary the flow of electrons through the valve from F to P, and therefore vary the plate current.

Fig. 27 indicates this more exactly. It is a curve showing how the plate current varies as the grid potential varies. Potentials to the left of O are negative and to the right of O positive.

When the grid has the negative potential OB it repels all the electrons from F, and there is no " plate current." As the potential of the grid rises to zero (O), *i.e.* becomes *less negative,* the plate current increases, as shown by the curve, to the value OA. As the grid potential becomes more and more positive the plate current rises more and more according to the curve ACD. A curve of this kind is called a *characteristic curve of the valve.*

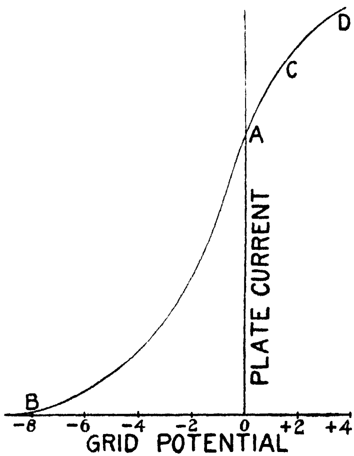


FIG. 27.

In a receiver the varying oscillations in the receiving aerial due to the arriving waves are passed on to the grid so that the grid potential is varying accordingly: this immediately produces corresponding variations in the plate circuit, and these plate current variations are used in the telephones and loud speakers. But, of course, they must be *rectified* in order that the telephones, etc., may respond to them, and if possible we want to *magnify* them so as to get a big volume of sound. Hence it is that in modern receivers the valve is used in two ways, viz. (1) as a **rectifying detector,** (2) as an **amplifier.**

(1) USING A VALVE FOR AMPLIFYING OR MAGNIFYING.—Consider the *steepest* part of the valve curve shown in Fig. 28. Suppose the grid of the valve (when no signals are

being received) to be somehow or other at a negative potential represented by OA (this is done by joining the grid to the negative pole of a small dry battery known as the *grid bias battery*). A steady plate current will be passing, represented by AF. Now suppose wireless waves arrive and oscillations are conducted to the grid. These will vary the voltage of the grid, the positive half waves causing the grid potential to be higher and equal to OB, say, and the negative half waves causing it to be an equal amount lower, *i.e.* equal to OC (for simplicity we are not taking a modulated wave).

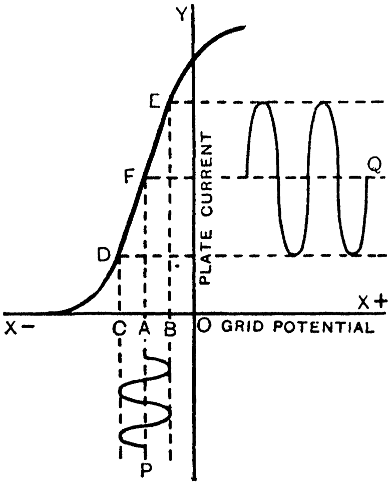


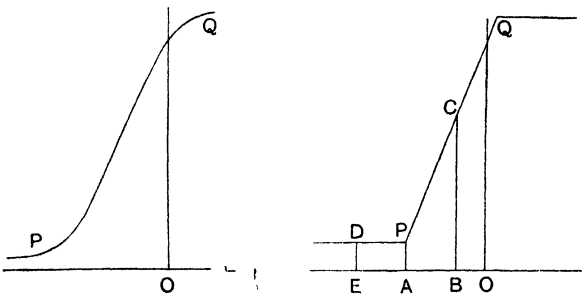
FIG. 28.

When the grid potential is OB the plate current will have increased from AF to BE, and when the grid potential is OC the plate current will have fallen to CD. Thus as the grid potential swings to and fro (due to the arriving waves) between OB and OC, the plate current swings between BE and CD, and further, the plate current changes follow the grid potential changes, and therefore the incoming waves, no matter how rapid the changes may be.

As we are working on the *very steep part* of the curve, however, a small jump from C to B causes a big jump from D to E, and this will be more pronounced the steeper the curve. It will be seen by comparing the two curves P and Q, where P represents the potential swings applied to the grid from the aerial, and Q the current swings in the

plate circuit, that the swing of Q will be bigger and bigger the steeper the curve. Thus the valve has amplified or magnified the variations impressed upon the grid. For amplification the valve should be so arranged that the steep part of its curve is used.

There is one point to note. Fig. 28 indicates magnification when the steep part of the curve is used, but P shows *potential* changes on the grid and Q the resulting *current* changes in the plate circuit, and to get a proper idea as to what "magnifying" is done by the valve the current changes Q should be converted into potential changes, and *the potential changes on the grid compared with the potential*



(*a*) Fig. 29. (*b*)

changes they cause on the plate. It is not necessary in this book to show how this can be done, so we will merely say this:—Valve manufacturers give us what is called the *amplification factor* of a valve: if this factor is given as, say, 50 it means that a change of 1 volt potential applied to the grid of the valve produces (under certain conditions) a change of 50 volts in the plate potential. Just note this fact here: for details some book on Wireless must be consulted.

(2) Using a Valve for Rectification or Detection. —Consider, not the straight steep part, but the parts of

the valve curve where the *bending* is greatest, *i.e.* the "knees" P and Q [Fig. 29 (*a*)]. So that you may grasp the idea we have exaggerated these in Fig. 29 (*a*), and to make the explanation still simpler we will exaggerate them still more for a moment as in Fig. 29 (*b*).

With this curve let the grid potential be equal to OA when no waves are passing, in which case the plate current is AP. When wireless waves arrive the negative half-wave lowers the potential of the grid to OE, but the plate current does not alter—it is ED, which is the same as its original value AP. When the positive half-wave arrives the grid potential rises to B and the plate current becomes BC. We thus get a plate current variation from AP to BC when the positive pulses arrive, but not when the negative pulses arrive. The valve is therefore responding, as it were, to swings in one direction only: it is refusing those "half puffs" previously mentioned. To utilise this rectifying property, then, the valve must be so arranged that the bending part of the curve is used.

The above explanation is rather elementary and approximate, but it will answer our present purpose.

This method of rectifying by a detector valve is known as *anode bend rectification.* Anotner method known as *grid leak rectification* is often used. We cannot go into details here, but you will recognise it by the fact that a small condenser is joined to the grid of the detector valve and that a resistance is either across the condenser or joined between the grid and positive of the accumulator.

There are various ways of coupling up the valves to pass the plate variations of one to the grid of the next, and there are valves with several grids (the *pentode* valve for example has three grids and the *pentagrid* valve five grids): but again for these some book on Wireless must be consulted.

CHAPTER III

THE ABC OF PRACTICAL TELEVISION

EVERYONE has heard the expressions " low definition " and " high definition " used in connection with television. The whole question of definition and its associated difficulties is dealt with in Chapter IV., but for the present we may take it that the expressions explain themselves: a " high definition picture " is evidently one in which the minute details—the small variations of light and shade—are clearly shown, whilst a " low definition picture " is one in which the details are not so clearly portrayed—the texture of the picture is coarser. Low definition (L.D.) television was first *broadcast* from the old 2LO station in 1926, and in September 1929 a regular broadcast was instituted by the B.B.C.; but high definition (H.D.) will be the television of the future.

In this chapter we will deal with the principles and practice—the groundwork—of practical television. Now the L.D. transmissions of the B.B.C. ceased when preparations began for H.D., but all L.D. principles and appliances are used in H.D. and must therefore be known. Hence *for simplicity, and to follow the historical and logical sequence,* we will apply our principles to L.D. methods in this chapter, taking the B.B.C.'s late low definition as an illustration: *this will best help the beginner.*

1. The Similarity between Sound and Vision Broadcasting

There is a certain similarity between " ordinary " wireless and television: you will readily see this if we first put the general idea in a nutshell as follows:—

The person whose face, say, is to be televised is seated in the studio, and a narrow beam of light from a lamp is

caused to *move quickly and in a regular manner* over his face: it is in fact "scanned" by a small spot-light somewhat after the style mentioned on page 29. The light reflected from the different parts of the face is caused to fall upon an appliance known as a *photo-electric cell*, the chief point about which is that it gives a current when light falls on it, and the greater the amount of light the stronger is the current. Thus in our television case, more light will be reflected when the spot-light passes over the teeth than when it passes over the dark hair, and therefore the current given by the cell will be greater in the first case than in the second case. Hence the current from the cell will be a constantly varying one, depending on the position of the spot-light on the face at any instant. This varying current is then amplified and superimposed upon the high frequency aerial oscillations which give rise to the carrier wave. Thus the carrier wave is *modulated* and passes on—a complicated aether wave depending on the variation in the light reflected from the various parts of the face of the person being televised.

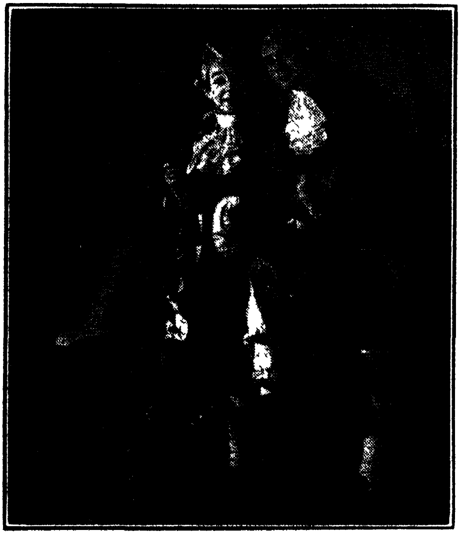


FIG. 30. George Mozart as the Court Chamberlain and John Hendrik as the Prince in the B.B.C. Television (low definition) Musical Comedy "Rokoko."

You see, then, the similarity at the sending end. In sound broadcasting the carrier wave is modulated in a way depending on the varying current from a microphone which, in turn, depends on the words spoken. In television the carrier wave is modulated in a way depending on the varying current from the photo-electric cell which, in turn, depends on the light reflected from the various parts of the face being televised. In the one case we change from a varying sound to a corresponding varying current by means of a microphone: in the other case we change from a varying light to a corresponding varying current by means of a photo-electric cell: and in both cases the varying current is caused to modulate the carrier wave passing out from the transmitting station.

Now let us come to the receiving end. The arriving waves set up oscillations in the receiving aerial corresponding to those in the transmitting aerial. These are conducted to a wireless receiver in the usual way, but the output terminals of the receiver instead of being joined to a loud speaker are connected to the terminals of a *neon lamp*. Other devices can be used instead of the neon lamp. Thus we get a varying illumination of the neon depending on the varying signal from the receiver which, when traced right back to the beginning, depends on the varying light from the face televised. By an arrangement to be explained presently, the varying illumination of the neon builds itself up into the image of the face in the studio.

You thus see the similarity at the receiving end. In sound broadcasting the loud speaker changes the current signal of the receiver into a varying sound which reproduces the voice in the studio. In television the neon lamp changes the signal of the receiver into a varying light which is caused to reproduce the face in the studio. In the one case we change from current to sound by a loud speaker, and in the other case from current to light by a neon lamp (or, of course, other device, as shown later).

2. The Scanning Disc and its Motor

These are used both at the sending end and at the receiving end. Briefly, the disc is a circular sheet of metal provided with a number of small square holes arranged at equal angular distances along a curve which is a well-known *spiral* (to the mathematician) as shown in Fig. 31. Starting at the outermost hole A and going on to B you will notice that each hole is a little nearer to the centre than the one immediately in front of it. In this country the standard number of holes *in low definition television* was 30. The drop in radius from the beginning to the end of the spiral, *i.e.* the difference between the radii OA and OB is called the *pitch*, and the side of each of the square holes is nearly $\frac{1}{30}$ of the pitch.

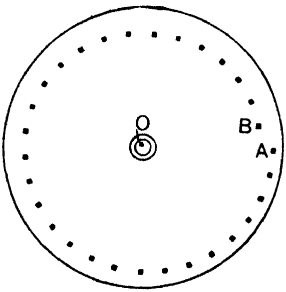


FIG. 31.

A scanning disc is mounted at its centre on the shaft of a motor and rotates with the motor shaft, the speed in the Baird (B.B.C.) low definition system being 12½ revolutions per second, or 750 revolutions per minute.

Although the actual area scanned at the transmitting end and the actual size of picture at the receiving end depend on the dimensions of the respective discs, the receiving disc need not, of course, be the same size as that at the transmitter. They must, however, have the same number of holes, be both constructed in the way we have indicated, and they must run at the same speed and be "in step" with each other, *i.e.* hole 1 of the receiving disc must be in a corresponding position to hole 1 of the transmitting disc at every instant: but this latter fact will be understood later.

Suitable scanning discs for reception are generally of aluminium, of 15 to 20 inches or so in diameter,

and painted a dead black so as not to reflect light. Transmitting discs are larger.

Suitable television motors for reception can be purchased at a reasonable price. They need only be small—of the order $\frac{1}{30}$ to $\frac{1}{15}$ of a horse-power. The "universal" is perhaps the most satisfactory for television purposes, for it can be used on either alternating or direct current supplies: its speed can be controlled by varying the voltage applied to it, and this can be done by means of a variable resistance in series with the machine.

3. The Photo-Electric Cell

This is a device used at the transmitting end for converting the varying light from the person or object televised into a corresponding varying current which is used to modulate the carrier wave of the transmitting station.

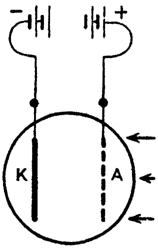


FIG 32.

Hertz, in 1887, and then Hallwachs, in 1888, noticed that when light of a certain kind fell upon certain metals which were negatively charged, *i.e.* had a surplus of negative electrons, the metals lost their charge. The effect was called *photo-electric emission* or the *photo-electric effect*, and the explanation is that the aether disturbance known as light sets the electrons in the metal in such violent agitation that finally the movement of some of them becomes so great that they are ejected. The early experimenters mainly used negatively charged plates of zinc and aluminium, and light of the violet type. Further experiments, however, soon showed that the metals *potassium*, *rubidium*, and *caesium* gave good results with *ordinary* light, especially when they were treated in a certain way.

Suppose K (Fig. 32) is a sensitive metal plate—a copper or silver plate coated with potassium on the right-hand face in the figure—and A a metal grid; and further

suppose K is joined to the negative pole and A to the positive pole of a battery, so that K has a surplus of negative electrons or is negatively charged, and A has a deficit of electrons or is positively charged. We will suppose K and A to be in a glass globe from which the air has been exhausted.

Now suppose a beam of light from a lamp is projected through the grid A to the potassium face of K. Negative electrons will be dragged out of K: these electrons will be repelled by K and attracted by A, and will rush off towards A so that a continuous *electronic* current will be flowing in the circuit in the direction K to A through the space between the plates, and from A through the wire, etc., to K. Moreover an intense beam of light ejects more electrons and therefore causes a bigger current to flow than a beam which is not very strong. The current varies in strength almost exactly in proportion to the intensity of the light falling on the sensitive plate.

In one type of photo-electric cell, K (spoken of as the *cathode*) and A (spoken of as the *anode*) are in a glass globe from which all the air has been withdrawn and the cell is called a *hard* or *vacuum cell*. In another type the glass globe contains one of the inert gases, generally *argon* or *helium* at a low pressure of about $\frac{1}{5000}$ of the pressure of the atmosphere, and the cell is referred to as a *gas-filled* or *soft cell*. In a vacuum cell the current through the cell is that carried by the electrons liberated from the cathode: in a gas-filled cell some of the electrons from the cathode collide with the gas particles and detach more electrons (this is called *ionisation*), and these additional electrons are added to the original flow. The gas-filled cell gives a bigger current for a given amount of light, but the vacuum cell is more constant, more stable, in its action (and especially at high frequencies—see later): for low definition television gas-filled cells have been (and are) largely used, but for high definition work the vacuum cell seems to be essential.

One form of photo-electric cell consists of a glass bulb rather flat at one side (Fig. 33). This flat side is covered on the inside with a thin deposit of copper or silver, and then on this is deposited a layer of potassium or caesium: this forms the sensitive plate or cathode. In front of the cathode is a metal ring covered with a grid of fine wires: this forms the anode. The light is projected into the cell in the direction indicated by the arrow. Connections to the anode and cathode are made by two platinum wires fused through the glass. Another type is shown in Fig. 34: in it the cathode is caesium deposited on oxide of silver, and in its best form the cell is 10 times more sensitive than a potassium on copper cell: in fact the potassium cell is now almost obsolete unless the light used is of a bluish type.

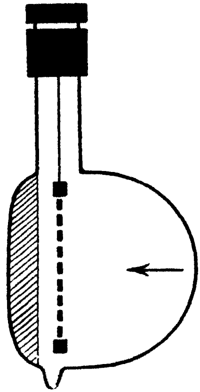


FIG. 33.

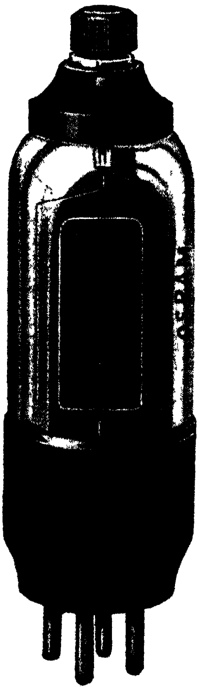


FIG. 34.
TELE. U.T.D.

Incidentally, a new and improved form of photo-electric cell has appeared (it makes use of what is known as *secondary electron emission*) which gives a much bigger current for a given amount of light falling on the cathode. It has opened out new possibilities so far as photo-electric cell work in television is concerned. We shall refer to it later.

4. The Neon Lamp

Neon is one of the inert gases, and it has the property that if *rarefied* neon is contained in, say, a glass tube closed

at the ends, with a piece of platinum wire fused through the glass at each end, and if an electric discharge be passed through it, the whole tube glows with a rich red-orange light. You have probably seen neon tubes used for advertising purposes. Letters and figures are made of glass tubing and the tubes contain rarefied neon; a high pressure alternating current is applied to the terminals, with the result that the letters and figures are strikingly illuminated.

Suppose we have two metal plates A and K parallel to each other and say about 2 millimetres apart in a glass vessel containing rarefied neon, the plates having platinum wires attached to them which pass through the glass for connecting purposes. Let A and K be now connected to a powerful battery or to a direct current mains supply, A to the positive and K to the negative, so that A is the anode and K the cathode.

Now at a certain *gas pressure* the tendency of a discharge is to go from the back of one plate to the back of the other and not confine itself to the narrow space between the two plates. It requires an electric pressure to be applied to the terminals of A and K of the order of 180 to 200 volts (called the *starting* or *striking voltage*) to start this discharge, and when it does begin the back of K—the negative electrode or cathode—becomes coated with a yellowish orange colour. If, when this steady glow is on, we increase the voltage applied to A and K the glow becomes more intense, and if we lessen this extra voltage the glow becomes less intense. The glow increases and decreases as we increase and decrease the extra voltage applied over and above the working voltage, and moreover the change in illumination occurs immediately we change the voltage—there is no waiting—no lag. It will be clear, therefore, that if we join the neon lamp to the output terminals of a wireless receiver and use the varying output of the receiver to supply the extra voltages over and above the working voltage, we will get a varying illumination of K depending on the varying output of the wireless receiver.

There are various forms of neon lamps—and modified gas-discharge lamps—on the market, but the general principle is the same in all, so we need only refer to one or two as examples. A type known as the *plate neon lamp* has been largely used for getting television at home: in one form (Figs. 35, 36) the electrodes are of nickel or iron, and the construction will be readily understood from the figures. The plate is the cathode and the varying illumination on this is used to build up the picture.

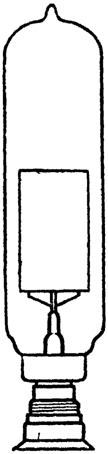


FIG. 35.

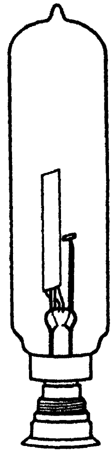


FIG. 36.

Another type often used was the *beehive neon lamp*. This is a usual round bulb lamp inside which is a spiral shaped like a bee-hive, and below this, a flat plate. These two elements are joined to the lamp terminals. When a direct current passes one of the elements glows: the lamp is connected up so that the beehive is the glowing element.

More brilliant light sources are obtained by using a mixture of gases instead of simply neon. A usual type

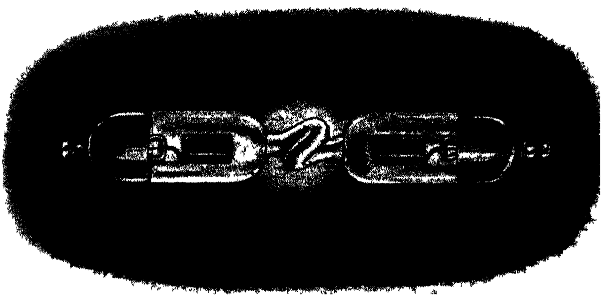


FIG. 37.

uses mercury vapour and neon and is spoken of as a *mercury-neon lamp*: it gives a bluish-white light.

A high intensity gas-discharge lamp known as the *Ti lamp* is shown in Fig. 37. It consists of a tube of special glass about ½ inch in diameter, the glass being formed into a curl at the centre, and when in use for television purposes it is arranged that this curl is facing the observer. A cylindrical electrode is fixed in the tube at each end and these are joined to the terminals. The lamp contains neon, mercury, argon, and helium in a determined proportion, its striking voltage is of the order 275 volts, and the discharge through the tube gives an intense, even illumination of a violet hue.

5. Sending and Receiving with Disc Scanning

We can now examine the process of low definition television with disc scanning both at the sending and receiving ends.

(1) AT THE SENDING END.—The general idea will be gathered from Fig. 38. We require a powerful source of light: this is shown at L and consists of a high intensity arc lamp in a suitable case fitted with a funnel in front through which the light passes out. R is a reflector which can be adjusted to ensure that the light passes exactly as required. The light is focused on a mask M which has a rectangular opening (adjustable) and matters are arranged that this opening is covered with a uniform illumination.

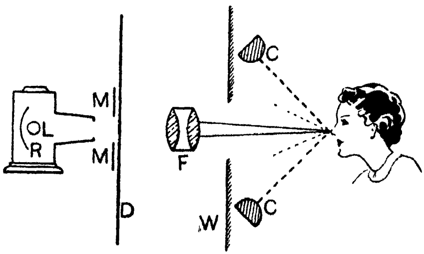
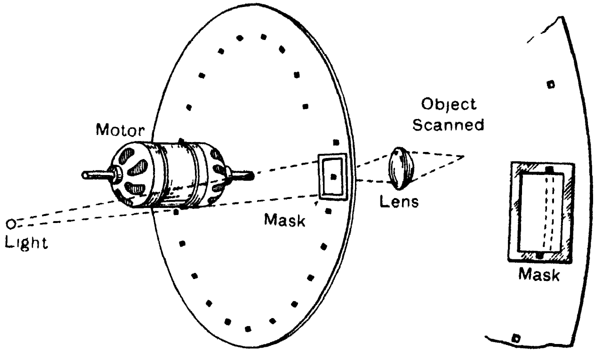


FIG. 38.

Next we come to a large scanning disc D with its 30



(*a*) (*b*)

FIG 39

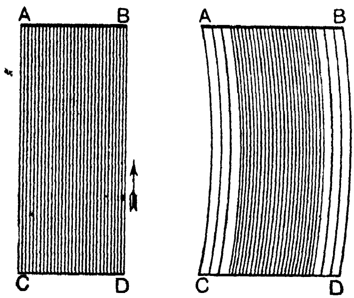
holes in a spiral, the disc being so arranged that when it rotates in a vertical plane, *i.e.* about a horizontal axle, each of the 30 holes passes in turn through the light beam coming through the mask opening. For this to happen the lamp, of course, must not be opposite the centre of the disc but off to one side towards the rim so that the holes, one after the other, *sweep through* the beam of light. The disc is fixed on the horizontal axle of a motor, and rotates with the motor shaft.

Next to this comes the lens F by which the light is focused on the person to be televised: this lens is adjusted for the best average focusing on the person, and this depends on the distance between him and the disc. But forget about this lens for a moment—imagine it is not there. Lenses sometimes turn images upside down and from left to right, and so on, and as " direction " plays an important part here, it will only confuse you if we take into account the action of a lens at this stage.

Having settled, then, that we are going to neglect the lens, we will go back and be a little more definite about the position of the lamp L in relation to the disc. We will take it that the lamp is on the right-hand side of the motor (we are looking at the disc face from the left of the figure)

and therefore opposite the right-hand half of the disc face. We will also take it that the disc is revolving *counter-clockwise* (viewed from the left), and therefore that the holes, one after the other, sweep *upwards* through the beam of light. (See Fig. 39.)

Now to resume. The next item in our arrangement shown in Fig. 38 is a wall W with an opening (fitted with plate glass) through which the light passes. This entirely shuts off the apparatus on the left from the "studio" on the right. The studio is lined with copper to prevent any disturbing electrical effects, and is treated "for acoustics" the same as a sound broadcasting studio. At the back of the studio is a screen—generally called the back screen—and it is just in front of this that the person to be televised stands or sits as the case may be. C C are photo-electric cells—really five are used—so arranged that light reflected from the person falls upon the cathodes of the cells.



(*a*) FIG. 40. (*b*)

As the disc rotates, each hole comes in turn into the light beam and travels upwards through the beam. During this upward journey light passes through the hole, and therefore a "spot-light" due to a narrow beam through the hole sweeps up the back screen. When the first hole has passed out at the top the second hole comes into action at the bottom [Fig. 39(*b*)], and it also traces a more or less vertical strip of light on the screen. As, however, this second hole is a little nearer to the centre of the disc than the first hole, the vertical strip of light it causes to be traced on the screen is a little to the left of the vertical strip due to the first hole. When this hole has passed on the third hole comes into operation, but as it is a little

more towards the centre of the disc than the second the vertical strip of light on the screen due to it is a little to the left of the previous one. This action is repeated by each hole in turn, so that by the time the disc has made one revolution, 30 more or less vertical light strips will have been traced on the screen one after the other, somewhat as shown in Fig. 40(*a*). We will call this area ABCD on the screen the *light area*.

This area is really *slightly* curved since we are using a disc [Fig. 40(*b*)], but this is negligible. Further, Baird made the first three holes of the disc and the last three rectangular instead of square: this has the effect of concentrating the picture details towards the central parts where they are wanted. Do not worry about this, however.

Again it will be noticed that the width of the light area (ABCD of Fig. 40) is that due to 30 light strips placed side by side, and therefore is governed by the *pitch* of the disc (and also by the distance between disc and back screen). The height of the light area depends upon the distance between one hole and the next (and also on the distance between disc and screen). The mask cut-out is of such a size that one hole passes off the light area just as the next hole comes into it, *i.e. there is never more than one spot-light on the area at any one time.* As a matter of fact the mask cut-out is so arranged that one hole really passes out of the light area at the top just *a little before* the next hole comes into it at the bottom. This means that when the spot-light passes off the area at the top there is for a small fraction of a second no light falling on the screen, for the following hole has not yet got into the area. We have indicated this by a black line at the top of Fig. 40. See also Fig. 39(*b*).

Let us now imagine the face of a person to be situated in front of the screen in the position of the light area, and that the disc is started rotating: the spot-lights will sweep over the face in the manner already indicated, and if you were looking you would see the whole face by virtue of that

"lag" of the eye, viz. persistence of vision, although only one spot-light is on the face at any one instant.

But instead of your eyes viewing the face, consider the photo-electric cell as an eye viewing the face. Unlike your eye the photo-electric cell has no persistence of vision, so that it responds immediately to the light reflected from the small area where the spot-light happens to be, and then as the spot moves so the response of the cell changes immediately to the new conditions, *i.e.* according to the light reflected from the new small area where the spot-light happens to be. Thus as the face is scanned by the spot-light varying amounts of light are reflected from the various parts according to the light and shade—more light from the brow, for instance, than from the dark eyebrows —and these varying amounts of light falling on the cathodes of the cells cause them to give a varying current —a bigger current with the light from the brow than with the light from the dark eyebrows. Thus the photo-electric cells pick up the varying reflected light as the spot-lights sweep over the face and translate it into an equivalent varying current—a current changing in the same way as the reflected light is changing.

This varying current from the photo-electric cells is very small, and so it is magnified or amplified, and finally caused to modulate the carrier wave which is passing out from the transmitting aerial. From the television point of view, however, the process need not be considered beyond this stage.

The point to remember is that we have in the transmitting aerial a high frequency oscillatory current varying up and down in strength in a complicated way depending on the "face" televised, and a complicated aether wave passing out from the transmitting aerial—an aether wave which has been modulated, not by the voice of a speaker or singer as in sound broadcasting, but by the varying light reflected from the various parts of the face in question.

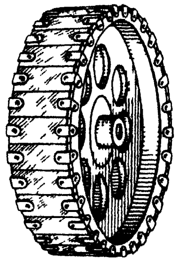


FIG 50.

plate circuits of valves and the neon and coils are supplied with D.C.): we then use the varying signal in the plate circuit of the output valve to modulate, via the transformer, the glow of the neon.

In the above we assumed the neon and synchronising coils to be in series. Sometimes, however, an extra output valve is fitted in the receiver and the synchronising coils are in the output circuit of this valve.

8. Sending and Receiving Television with Mirror Drum Scanning

The mirror drum method of scanning was also used by the B.B.C.: it is an improvement on the disc machine for it gives better and larger pictures, and these are projected on a screen—a method which most people prefer to the usual "peep in" method of the disc.

The appliance consists of an aluminium drum capable of rotation and driven by a motor in the usual way. Round the outer circumference are arranged 30 rectangular mirrors, each being set at a slight angle to the preceding one. Fig. 50 shows the construction of a typical drum, and Fig. 51 will explain the principle of its scanning action.

In the figure suppose the drum is rotating in a

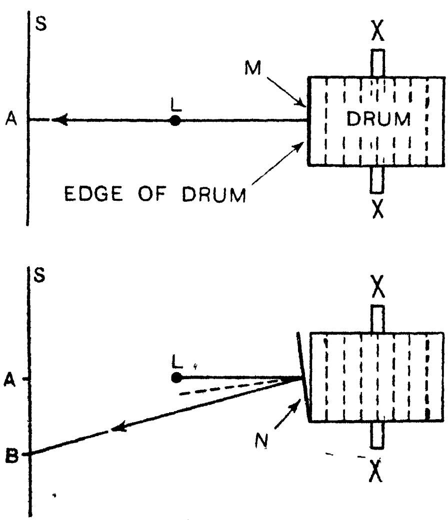


FIG. 51.

vertical plane about the horizontal axle XX: let M be a mirror on the circumference, S a screen, and L a light source. The figure is only to show the *principle*—the position of L in practice will be seen presently. Light from L falls on M, is reflected and focused on the screen, so that as the drum revolves a strip of light (one of the " journeys " of Fig. 40) is traced on the screen at A in a direction at right angles to the page of this book (the necessary lenses are not shown). Now the next mirror N on the edge of the drum comes into the beam from L, and as the drum

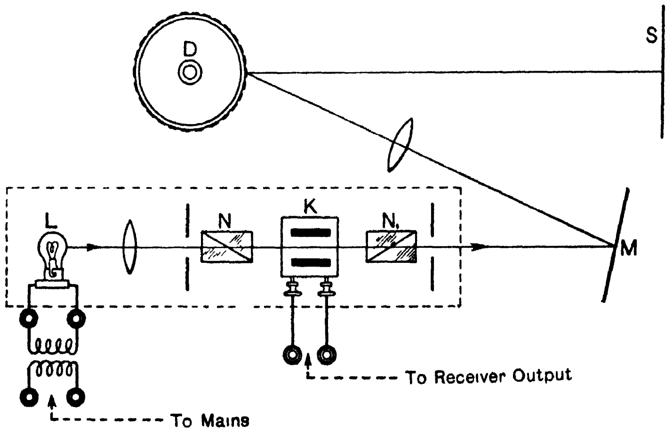


FIG. 52.

continues to rotate this mirror also causes a vertical strip of light to be traced on the screen. But N is slightly tilted compared with M so that this second vertical light journey on the screen is a little to one side of the first strip. This is indicated in Fig. 51 where we have exaggerated the tilting of the second mirror N, getting the second vertical strip of light at B. It is clear, however, that [illegible] tilting each mirror on the [illegible] out by the varying light

We need say nothing further about the drum at the sending end. Coming to the receiving end, Fig. 52 will explain the arrangement of a typical mirror drum receiver (using A.C. mains). In this, L is a powerful source of light of the 12 volt 100 watt bunched filament type: it is connected to the secondary of a mains transformer, the primary being, of course, coupled to the mains. The light from L passes through a condensing lens and then through an arrangement known as the "Kerr-cell-Nicol-prisms" combination. This consists of a Kerr cell K (which is joined to the output of the receiver just as the neon lamp was in the disc visor) in between two Nicol prisms N, N_1: but we will explain these things and their action presently. The light emerging from these falls upon an inclined mirror M and is reflected through a focusing lens to the mirror drum D from which it is again reflected to the screen S. From what has been said it will be clear that as the drum rotates a "picture area" will be scanned on the screen, and if we can "modulate" the light by the varying output of the receiver a picture will be built up on the screen: that modulation is done with the help of the Kerr-cell-Nicol-prisms combination. Incidentally, the modern form of Kerr cell used in television is generally spoken of as a "Grid cell."

The drum is driven by a motor (750 revolutions per minute) which is fitted with synchronising gear (30-toothed wheel). We have said that an extra valve is often fitted to a receiver to supply the synchroniser: its terminals are joined to the output terminals in the plate circuit of this extra valve.

We can now examine the action of the Kerr-cell-Nicol-prisms combination and see how this modulation of the light from L is brought about.

9. The Kerr Cell (and Modern Grid Cell) and Nicol Prisms

We have seen (p. 21) that light is a form of wave-motion in the aether, and that it travels at a speed of 186,000

suppose K is joined to the negative pole and A to the positive pole of a battery, so that K has a surplus of negative electrons or is negatively charged, and A has a deficit of electrons or is positively charged. We will suppose K and A to be in a glass globe from which the air has been exhausted.

Now suppose a beam of light from a lamp is projected through the grid A to the potassium face of K. Negative electrons will be dragged out of K: these electrons will be repelled by K and attracted by A, and will rush off towards A so that a continuous *electronic* current will be flowing in the circuit in the direction K to A through the space between the plates, and from A through the wire, etc., to K. Moreover an intense beam of light ejects more electrons and therefore causes a bigger current to flow than a beam which is not very strong. The current varies in strength almost exactly in proportion to the intensity of the light falling on the sensitive plate.

In one type of photo-electric cell, K (spoken of as the *cathode*) and A (spoken of as the *anode*) are in a glass globe from which all the air has been withdrawn and the cell is called a *hard* or *vacuum cell.* In another type the glass globe contains one of the inert gases, generally *argon* or *helium* at a low pressure of about $\frac{1}{5000}$ of the pressure of the atmosphere, and the cell is referred to as a *gas-filled* or *soft cell.* In a vacuum cell the current through the cell is that carried by the electrons liberated from the cathode: in a gas-filled cell some of the electrons from the cathode collide with the gas particles and detach more electrons (this is called *ionisation*), and these additional electrons are added to the original flow. The gas-filled cell gives a bigger current for a given amount of light, but the vacuum cell is more constant, more stable, in its action (and especially at high frequencies—see later): for low definition television gas-filled cells have been (and are) largely used, but for high definition work the vacuum cell seems to be essential.

CHAPTER IV

HIGH DEFINITION TELEVISION—SOME DIFFICULTIES AND WHY ULTRA-SHORT WAVES ARE NECESSARY

FROM what has been said so far you will understand the necessity for scanning in television. If we merely illuminated the face of a person and allowed the reflected light to fall on a photo-electric cell, the latter's response would be simply a steady one depending on the *total* illumination. We must break it up into small pieces and get the separate effect of each small piece, and it is clear that the more small pieces we have, the more detailed will be the light and shade of the picture, *i.e.* the higher will be the " definition."

An engraver uses rather a similar idea in making " half-tone blocks " for printing purposes. He uses a " screen " in between his lens and the photograph of which a block is required. For high class printing on art paper a fine screen is used—say 200 lines to the inch—and the picture shows the details very clearly: for an ordinary printing paper a screen say of 133 or 150 lines to the inch is used, but the resulting picture, although still good, is not so detailed: with coarser screens—less lines to the inch—the picture is coarser. You have probably seen examples of fairly coarse pictures in certain newspapers: the picture is lacking in detail—you can even see the individual " dots "—and it must be held at a greater distance from the eye than is usual in order to appreciate it.

1. High Definition and Low Definition

Clearly, then, the greater the number of scanning lines in television the higher will be the definition. There is no

definite dividing line, but as a general guide we may take the following classification:—

(*a*) *Low definition transmissions.* These use up to 40 lines in a complete scan: the transmission can be on the ordinary broadcast band of waves.

(*b*) *Medium definition transmissions.* These use from 40 to about 100 lines per scan: the transmission can be on short waves.

(*c*) *High definition transmissions.* These use over 100 scanning lines: the transmission *must* be on *ultra-short* waves (below 10 metres), as you will see presently.

Although in most respects " the more lines the better " is true, there are practical limitations due to difficulties connected with the small amount of light from small " spots," to scanning difficulties, to transmission difficulties, and to difficulties connected with the " wireless " part of the apparatus. The Television Committee decided (practically) on 240-line scanning. Much very successful high definition experimental work has been done with 180-line scanning, and in fact many television workers contend that 180 is sufficient. On the other hand, television research has been successful with scannings of 500 lines and more. Our first H.D. station has been housed at the Alexandra Palace, and Baird led off with 240 and Marconi E.M.I. with 405 lines.

2. Picture Size

We have said that the B.B.C. low definition system (30 lines) was adapted for " close-ups "—head and shoulders, three-quarter height single person or two persons—and as most of us are taller than we are broad, vertical scanning and a light area (and picture area) greater in height than in width is suitable: the ratio of height to width was in fact of the order 7 : 3.

This, however, is an awkward size for scenes with breadth and movement, and so most modern high definition

systems have followed the custom of the cinema. The silent film used a picture frame the ratio of height to width of which was 3 : 4 (Fig. 64). When the talking-films arrived a strip down the side had to be used for the sound record, thus making the picture frame more square in shape. This shape, however, did not fit in with the screens already in use in the theatres, and so a strip had to be taken off the bottom to bring the shape back to the original standard 3 : 4.

The modern picture standard then is: vertical : horizontal = 3 : 4, and the scanning is done horizontally in the direction of the greater of the two dimensions. Thus if ABEF (Fig. 65) be the scanning area, the spot starts, say at A, and sweeps out the line AB: then the spot starts at

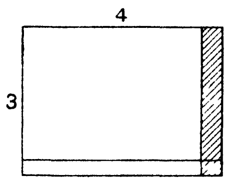


FIG. 64.

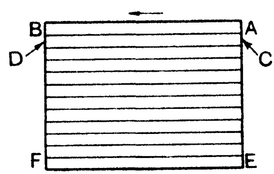


FIG. 65.

C and sweeps out the line CD, this line being below AB and " edge to edge " with it: this is continued until the whole scan is completed (180, 240, etc., lines, as the case may be), the last line being from E to F. The next scan begins again at A and the action is repeated.

3. Picture Frequency and Line Frequency

In low definition television there were $12\frac{1}{2}$ complete scans or pictures per second, and this is referred to as the *picture frequency*. In the cinema the silent film was run through the projector at the rate of 16 pictures per second, but with the advent of talking films the number was raised to 22-24. Now persistence of vision varies a little with different people, but in a general way the impression

on the retina of the eye lasts for from $\frac{1}{16}$ to $\frac{1}{10}$ second. Thus 24 per second ensures that the eye sees a continuous movement on the cinema screen, and not a jerky movement of still pictures one after the other. Again, 16 per second is fairly safe from this point of view, but $12\frac{1}{2}$ is getting dangerously low: it is rather too near the limiting value and there is the possibility that "flicker" will result. To avoid flicker and ensure a steady picture in television a higher number is desirable, and 25 complete scans or pictures per second is a usual picture frequency for high definition work. (50 has been used in some experiments.)

In low definition television, then, the picture frequency was $12\frac{1}{2}$ per second, and as there were 30 lines per scan or per picture, the number of scanning lines traced out in one second was $30 \times 12\frac{1}{2} = 375$: this is spoken of as the *line frequency*.

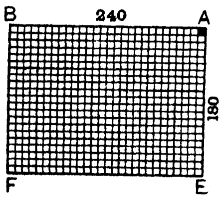


FIG. 66.

In 180-line high definition television at 25 pictures per second the scanning lines traced per second are $180 \times 25 = 4500$: thus the line frequency is twelve times and the picture frequency twice those of low definition television. With 240-line scanning the line frequency is $240 \times 25 = 6000$, *i.e.* sixteen times that of low definition.

Note that, as in all new advances in any science, a little irregularity exists in television as to the use of certain names and expressions. Thus picture frequency is often called *frame frequency*, the expression "picture frequency" being employed in another sense, viz. in relation to an aspect of frequency dealt with in Art. 5. No doubt all will be standardised in time. "Strip frequency" and "line frequency" are both used for number of lines per second.

4. Picture Elements

Look at Fig. 66 and imagine 180 lines scanned out (horizontal scanning) by a square spot-light. The length

AE is equal to that of 180 spot-lights placed in line, and the length AB is equal to that of $180 \times \frac{4}{3} = 240$ spot lights in line (since AB : AE = 4 : 3). The total light area ABFE is therefore equal to that of $180 \times 240 = 43{,}200$ spot-lights. Each square is a *picture element*, and we say that in 180-line scanning with a picture ratio 3 : 4 there are 43,200 *picture elements*. With 240-line scanning and the same picture size the number of picture elements is evidently $240 \times (240 \times \frac{4}{3}) = 240 \times 320 = 76{,}800$.

In the case of low definition television with 30-line scanning and a picture ratio 3 : 7 the number of picture elements is $30 \times (30 \times \frac{7}{3}) = 30 \times 70 = 2100$. Thus in high definition television, 180-line scanning gives over 20 times, and 240-line scanning over 36 times the number of picture elements of low-definition television. And remember the more the picture elements the higher is the fidelity of the picture.

5. Frequencies Required in Transmitting High Definition Television

We have dealt with *picture frequency* and *line frequency* —the number of pictures *per second* and the number of scanning lines *per second*. We come now to another aspect of " frequency " in connection with television—an electrical (and optical) aspect—which is of far-reaching consequences: it constitutes in fact one of the serious difficulties which television research workers and engineers have had to contend with.

In sound broadcasting, as you know, each station is given a certain wave-length (and frequency) for its carrier wave, and is expected to adhere to it to avoid interference with other stations. Now the carrier wave for the London Regional is 342 metres wave-length (approximately) and 877,000 cycles or 877 kilocycles frequency. (To get the frequency in kilocycles divide 300,000 by the wave-length in metres.) Suppose in the studio our lady soprano in front of the microphone " modulates the carrier " by producing a note of 1200 cycles frequency. The result of

this is that in the transmitting aerial we have what amounts to our original carrier frequency of 877,000 cycles and two other frequencies, one 1200 cycles *above* the carrier frequency (viz. 878,200 cycles) and the other 1200 cycles *below* the carrier frequency (viz. 875,800 cycles)—a total frequency "spread" from one side to the other of 2400 cycles. That simple modulation by the lady in question has caused a fairly big frequency spread in the aether, and this always happens when we modulate a carrier wave. The actual frequencies produced depend, you will notice, on the frequency of the modulation. All this can be readily proved and the "proof" is well known to physicists: if you are not one of these you must take our word for it. There is undoubtedly a big *aether spread* depending on the frequency of the modulation.

When we consider, then, the complex modulation due to, say, an orchestra or even the human voice, it will be clear that whilst each station must have a fixed carrier wave-length and frequency, a certain *sideband* allowance must be given below and above the station frequency to accommodate the modulation effects, and the present spacing between stations on this account is 9000 cycles or 9 kilocycles frequency. If you examine a list of wave-lengths of our broadcasting stations you will find this is the case. Thus London Regional is 342 metres wave-length and 877 kilocycles frequency: the next station on one side of it is Graz (Austria) with a wave-length of 338·6 metres and frequency 886 kilocycles, *i.e.* 9 *kilocycles more than London*: the next station on the other side of London is Poznan (Poland) with a wave-length of 345·6 metres and frequency 868 kilocycles, *i.e.* 9 *kilocycles less than London.* Note particularly that stations are separated from each other on a frequency basis not on a wave-length basis: try to think more in terms of "frequency" than in terms of "wave-length."

As a matter of fact the ear can distinguish sounds ranging from about 27 to 30,000 cycles per second (a few

can detect up to 40,000, but the *average* is in the region of 20,000 to 30,000). No attempt, however, is made to cover this range in broadcasting, for it takes an exceptionally good loud speaker to bring out notes below 45 and above 7000 cycles or 7 kilocycles. Hence for sound broadcasting a station spacing of 9 kilocycles to accommodate the modulation is fairly satisfactory (more would be better). But matters are different when we come to deal with the more stringent and discriminating eye and television.

Suppose we are scanning an area consisting of black and white squares rather after the style of a chess-board. We will assume this area to have the usual picture ratio 3 : 4, *i.e.* AE : AB = 3 : 4 (Fig. 66), and that the scanning is

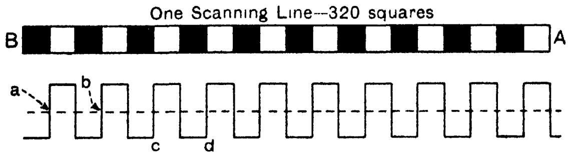


FIG. 67.

done horizontally with 240 lines. Further, we will assume that our square spot-light used in the scanning is exactly the same size as one square. Clearly, down the side AE we have 240 squares, each being the first square in a scanning line, and along AB we have $240 \times \frac{4}{3} = 320$ squares: the total picture elements in the scanned area is therefore $240 \times 320 = 76{,}800$ as already indicated.

Now consider the spot-light scanning the first line, say from A to B (Fig. 67). When it is on a black square very little light will be reflected and the response of the photo-electric cell will be small: when on a white square the reflected light will be great and the cell response will be large. Thus in scanning the first line of 320 squares there will be 160 current rises when white squares are involved and 160 current falls when black squares are involved,

and we may roughly represent the variation of the cell current as in Fig. 67 (this does not represent the case exactly, but it will answer our purpose). This current variation is, of course, used to modulate the carrier wave.

A little digression. You will remember that an alternating current flows *in opposite directions.* The photo-cell current certainly varies up and down in strength, but it always *flows in one direction.* You will note, however, that we have drawn a dotted line along the centre of the current variation curve. Students of Electricity will know that the variations we have got are really equivalent to an *alternating* current (like the square-topped curve) superimposed on a steady current like the dotted line—in fact we often say that the photo-cell current has an A.C. and a C.C. component. Do not worry about this. We merely mention it because of what we are going to say in the next paragraph: a full explanation is beyond the scope of this book.

Going back to the alternating current curve of Fig. 11, we said a " cycle " was represented by the curve from O to S, *i.e.* it included an up-loop and a down-loop. Similarly in Fig. 67 a " cycle " of the cell's current variation is represented by the curve from *a* to *b* (or *c* to *d*). Thus the total number of " cycles " during the scanning of the first line is $\frac{320}{2} = 160$. As there are 240 lines in a complete scan or picture the number of cycles during a scan is $160 \times 240 = 38{,}400$, and if there are 25 pictures per second the number of *cycles per second* in the varying current given by the cell (which is used to modulate the carrier) is $38{,}400 \times 25 = 960{,}000$. But " cycles per second " is what we have defined as " frequency," so the frequency applied to the carrier wave for modulation purposes, instead of being our lady vocalist's few cycles, is no less than 960,000 cycles or 960 kilocycles per second.

Of course this black and white pattern of squares is certainly a bad case of very abrupt changes from black to white, and nobody is particularly anxious to televise black

Photograph Courtesy of Baird Television Co

HIGH DEFINITION TELEVISION

Preparing for a Boxing Match at the Baird Experimental Studio prior to its television by the Intermediate Film System Only a medium amount of artificial flood-light is necessary for this work

and white squares. Nevertheless we may assume that 960 kilocycles represents the highest (fundamental) frequency to be used for modulation in 240-line television: it is taken as the standard to be catered for in 240-line scanning, and is often called the *video frequency* from the Latin meaning "I see." Strictly, however, it should be more than 960 kilocycles for there are strong harmonics in a case like this, and, moreover, allowance should be made for synchronising pulses: in America 10 per cent. addition is usual which brings the modulation frequency up to 1,067,000 cycles or 1067 kilocycles, *i.e.* 120 times the *whole station separation* of 9 kilocycles in sound broadcasting.

Remember, too, that the *total communication channel* must be from 1067 kilocycles above to 1067 kilocycles below, *i.e.* a total "space" of 2134 kilocycles. It is the big communication channel to allow for the big modulation frequencies (sidebands) necessary for high definition television that makes it impossible to send such television on the ordinary broadcasting waves which allow only 9 kilocycles separation between stations.

And if we try to save "space" in the aether by not catering for these big frequency bands in our H.D. apparatus we reduce the picture details accordingly.

A Digression on Arithmetic. Go back to our calculation and you will see that our video frequency (neglecting the 10 per cent. addition) was obtained by multiplying the number of picture elements by the number of pictures per second and dividing by 2. The steps in the working were (examine these)—

Frequency $= 240 \times (240 \times \frac{4}{3}) \times 25 \times \frac{1}{2} = 960{,}000$ cycles, and we can write a handy expression for the calculation thus—

$$\text{Frequency} = \frac{(\text{Scanning lines})^2 \times (\text{picture ratio}) \times (\text{pictures per sec.})}{2}$$

To resume:—As a further example take the case of 180-line scanning (horizontally), 25 pictures per second,

and the usual picture ratio of 3 : 4, and we get (neglecting the 10 per cent. addition)—

$$\text{Frequency} = \frac{180 \times 180 \times \frac{4}{3} \times 25}{2} = 540{,}000 \text{ cycles},$$

so that the frequency to be catered for in modulation (sidebands) is 540 kilocycles demanding a communication channel of 1080 kilocycles. This is not so severe a demand as that of the 240-line scanning, but it is big compared with the communication channel used in sound broadcasting. As with the 240-line scanning, this 180-line television cannot therefore be sent on the ordinary waves with the 9 kilocycles station separation.

Finally, if you work it out you will find that 400 lines means a frequency of over 2600 kilocycles, and a space of over 5300 kilocycles, whilst 500 lines means about 4000 and 8000 respectively.

Incidentally the preceding is the usual method of estimating the frequency for a given number of lines, etc. Modifications of the formula are employed by some workers, but we cannot go into the "why and wherefore" in this book.

6. Why We Must Transmit H.D. Television on Ultra-Short Waves

The following table summarises the main facts and figures given in the preceding section, and it should now be clear that owing to the large communication channel required in H.D. television to accommodate the modulation

Lines	Picture Ratio	Pictures per Second	Modulation Frequency (Cycles per sec.)	Modulation Frequency (Kilocycles per sec.)	Radio Channel (Kilo-cycles)
30	3 : 7	12½	13,000	13	26
180	3 : 4	25	540,000	540	1080
240	3 : 4	25	960,000	960	1920
400	3 : 4	25	2,666,000	2666	5332

frequencies (sidebands), such television cannot be sent on our ordinary broadcast waves with only 9 kilocycles separation between stations. To drive the idea home, however, we will take a definite example.

Let us imagine that we wish to set up a chain of H.D. television stations, and that we contemplate using, for our first station, the wave-length of the Scottish National (assuming it possible—*technically*—to do so: see page 93).

This has a wave-length of 285·7 metres and a frequency of 1050 kilocycles. Now if we assume the lower figure for 240-line television, viz. 960 kilocycles, and go 960 kilocycles above the Scottish we get the frequency $1050 + 960 = 2010$ kilocycles corresponding to a wave-length of $300{,}000 \div 2010 = 144$ metres approximately. If we go 960 kilocycles below the Scottish we get the frequency $1050 - 960 = 90$ kilocycles corresponding to a wave-length of $300{,}000 \div 90 = 3300$ metres approximately. To work this, the first of our chain of stations, we want, then, a clear "space" in the aether which comprises wave-lengths from 144 metres to 3300 metres.

Now the medium broadcasting band of wave-lengths is from 200 metres (Agen, France) to roughly 600 metres (Innsbruck, Austria, is 578 metres), and in this band alone there are over 100 broadcasting stations (at 9 kilocycles separation). All these therefore would have to close down —they would be practically useless. Waves from 600 metres to 2000 metres include some ship and aeroplane services and the whole of the long wave broadcasting band (about 1100-1950 metres wave-lengths), and these also would be "in the way." So also would some long wave ship to shore and commercial services worked on wave-lengths above 2000 metres, and so also some shorts below 200 metres. To provide our "space" all these would be rendered more or less useless—an intolerable state of affairs—"which is impossible."

And, moreover, if you had a receiver the components of which enabled you to tune in to the Scottish National

carrier, those same components would be unable to handle the big frequency spread of the television.

Fig. 68 will help to emphasise these points. The important fact is that owing to the big modulation frequencies (sidebands) required in high definition television *it cannot be transmitted on our ordinary wireless waves without rendering the present broadcasting stations practically useless*: and this part of the aether is literally packed with sound broadcasting stations separated from each other by 9 kilocycles frequency.

Fortunately there is plenty of elbow room in the aether if we utilise the *very short* waves, *i e.* the *ultra-short waves below* 10 *metres* in wave-length. Suppose we have a

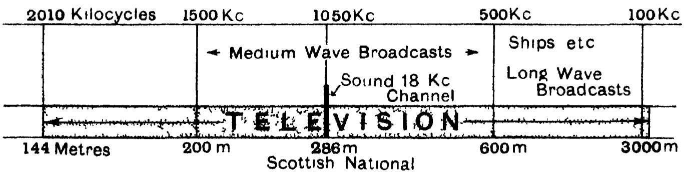


FIG 68

station with transmitting plant which sends out a carrier wave of 6 metres: the frequency is therefore $300{,}000 \div 6 = 50{,}000$ kilocycles. If we transmit 240-line television on this wave we want a frequency range up to $50{,}000 + 960 = 50{,}960$ kilocycles on one side of the station frequency, and a range down to $50{,}000 - 960 = 49{,}040$ kilocycles on the other. The wave-lengths corresponding to these two frequencies are 5·8 and 6·1 metres respectively—wave-lengths not so very different from the wave-length, viz. 6 metres, on which the vision is sent out. Thus in this ultra-short wave region, and sending the vision on 6 metres, we get our necessary space of nearly 2000 kilocycles in a wave-length band ranging from 5·8 to 6·1 metres only.

In fact taking the band of ultra-short waves from 10 metres down to, say, 3 metres, and assuming channels

of even 2000 kilocycles (for 240-line scanning), several television stations could be accommodated without interference.

Beginners are often puzzled as to how it is that there is all this elbow room on the ultra-short wave region, say from 3 to 10 metres wave-lengths. The trouble is due to thinking too much about wave-length and too little about frequency. Waves between 3 and 10 metres mean frequencies between 100,000 (*i.e.* 300,000 ÷ 3) and 30,000 kilocycles—*a range of* 70,000 *kilocycles*. On the other hand the whole of the medium waves used in broadcasting (say 200 to 500 metres) means frequencies between 1500 and 600 kilocycles—*a range of only* 900 *kilocycles*. Among the ultra-shorts, then, between 3 and 10 metres wave-length we have a " frequency space " about 80 times what we

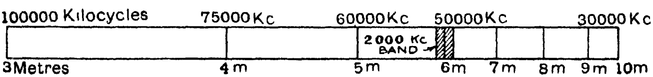


FIG. 69.

have in the whole medium broadcasting band of 200 to 500 metres wave-length. Between 4 and 5 metres wave-length—a difference in wave-length of only 1 metre—there is a " frequency space " of no less than 15,000 kilocycles, which would be more than enough for all the *sound* broadcasting stations in the world separated from each other by 9 kilocycles.

Fig. 69 will make the preceding points clear, and in conjunction with Fig. 68 will emphasise the fact that for H.D. television transmission *ultra-short* waves must be used, and that there is abundance of room in this region for what we require and for many H.D. television transmitting stations. Incidentally it follows that H.D. television (vision and sound being both sent out on ultra-short waves) should not interfere in any way with the present (sound) broadcasting.

Finally, there is another fact which indicates that ultra-short waves must be used for H.D. television transmission. If you look back to what we said about wireless transmission in Chapter II. (*e.g.* examine again Fig. 24) you will realise that the frequency of the carrier wave we use in broadcasting must be *very much higher* than the frequency of any *modulation* we may give to it. (Compare the carrier curves in Figs. 22, 24 with the modulation curve at (*a*) in Fig. 24.) Hence as we want a modulation space of the order of, say 2000 kilocycles in H.D. television, we must go into the ultra-short waves to find carriers of high enough frequencies for the purpose (*i.e.* to " carry " them). A 6 metre wave has a frequency of 50,000 kilocycles, which *will* answer the purpose: a 300 metre wave only has a frequency of 1000 kilocycles—which *won't* answer the purpose. It may be taken as a general guide that the carrier frequency should be of the order 25 times the maximum " carried frequency."

7. The Range of Ultra-Short Waves

There is a feature about these *ultra-short* waves which causes a certain difficulty, and that is their short range, *i.e.* the short distance from the transmitting station (compared with our ordinary and short waves) at which they can be successfully received. On this point, however, further research is necessary, for rather conflicting results have recently appeared: but this will not upset the general principles we are going to explain.

Some 60 miles above the earth's surface there is a layer of " ionised " air (page 48) which acts as a reflector of wireless waves, turning waves which have travelled upwards from the transmitter back again towards the earth: this is called the *Heaviside* or *E layer* or *ionosphere*. About 90 miles further up there is a second layer—the *Appleton*—which does the same: and there are others. These layers are ionised by rays from the sun, and they play an important part in wireless transmission and

reception: it is mainly due to them that long signalling distances such as we have in our "ordinary" wireless are possible, despite the curvature of the earth.

Consider a station S (Fig. 70) sending out wireless waves. Some travel along the ground as indicated by SX (these are spoken of as ground waves), and some travel upwards (these are spoken of as atmospheric or sky waves). With regard to the latter, they may be reflected at the Heaviside layer and be turned down to the earth so that they can be received at Y (even if there is a big hill between S and Y); they may pass on and be similarly reflected by the Appleton layer; and they may pass on and never return. What really happens depends on the time of day, etc., but most important of all, from our point of view, is that it depends on the wave-length.

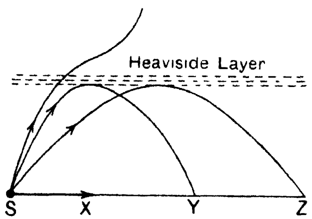


FIG. 70.

There are many interesting and important facts about these sky reflections so far as ordinary wireless transmission and reception are concerned (long, medium, and short waves). For details some good book on Wireless must be consulted, but the following facts may be briefly indicated:—

(*a*) In a general way we may say that at short distances from a station reception is mainly due to the ground wave. At greater distances the atmospheric wave comes in also. At very great distances the ground wave may have practically disappeared owing to the energy being absorbed and reception be due mainly to the "sky reflections."

(*b*) Short waves (say from 100 down to 13 metres wave-length) have a restricted ground wave, and beyond a comparatively short distance the atmospheric wave has to be relied upon: it is really this fact which accounts for many of the unexpected happenings in short wave reception

so well known to all short wave experimenters. With these short waves, then, the ground wave is effective near the station S, but disappears, say, at X (Fig. 70): no signal would be heard from X to Y, and then the atmospheric wave would be received. XY is called the *skip distance.* (Short waves are mainly reflected by the *Appleton* layer.)

And now we come to ultra-short waves, the waves below 10 metres wave-length which are used in high definition television, and the important fact about these seems to be that *they travel practically in straight lines, and those going upwards are not reflected by the Heaviside and Appleton layers.* The effect of this is that their range—the distance from the transmitting station at which they can be received — is limited, for there are no sky reflections to extend the distance.

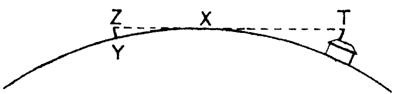


FIG. 71.

It is usual to regard the range of these ultra-shorts as being the " optical " or " horizon " distance from the transmitting station, but theory and experiments alike indicate that this is not quite true if applied in general to *all* the ultra-shorts. It is nearer correct the shorter the waves, but so far as the waves to be used in television are concerned (say 5-8 metres) we may take it they do follow the curvature of the earth *a little,* and that they do bend over and travel round obstacles—*e.g.* a hill—*a little.* Of course, even light (very short waves) which travels in straight lines does bend round obstacles a little—very little. However, as we only wish to deduce a general conclusion at this stage, we will assume the range of ultra-short television waves to be the " horizon distance."

Consider, for example, Fig. 71, where the curve represents the surface of the earth and T represents the aerial on the roof of the transmitting station. The " horizon distance " for the station is TX, and a receiver at ground level

anywhere between T and X will get the signals all right. Further to the left than X in the figure—say at Y—no signals would be received *at ground level.* If, however, we erect a receiving aerial YZ of such a height that it reaches the level TX, the signal will be received. In fact, the receiving aerial also has a " horizon distance " ZX, and this must be *added* to the horizon of the transmitting aerial to get the distance at which signals can be received. The range of Baird's Crystal Palace aerial was 30-40 miles.

So far we have assumed the ground to be " level," but it will be clear that the nature of the intervening ground will exert an influence. Look at Fig. 72, where T is the transmitter. The ultra-short waves such as TA are stopped by the hill, and waves such as TBC just pass it: but in both cases R is completely shadowed and receives no signals. If the transmitting aerial at T was raised to T′ until T′, B, R were in line (dotted line), or if the receiving aerial at R was raised up to the line TBC the signal would be received.

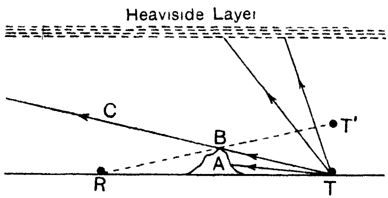


FIG. 72

Height of transmitting aerial and height of receiving aerial are therefore important points in H.D. television transmission and reception in view of the nature of ultra-short waves: the higher the two aerials the greater is the distance at which signals can be received.

Perhaps the best type of aerial for reception is that known as the " half-wave dipole " (half a wave in length), and it should be erected as high as possible: but this will be referred to later. Note that the sound and vision can be sent out on *wave-lengths* differing very little from each other when ultra-shorts are used: one aerial system can be used for both. But again more about this later.

CHAPTER V

AT THE SENDING END—HIGH DEFINITION TELEVISION

WE discussed in Chapter III. the two main methods employed in low definition television, viz. the *scanning disc* (sometimes called the *Nipkow disc* after the original inventor) and the *mirror drum*. Now we come to the systems practically employed in high definition television, and in this chapter we will concentrate on the apparatus and methods in use at the sending end.

1. The Spot-Light System

Little need be said about this system of H.D. television, for it is simply an extension of the method pioneered by Baird and fully described in Chapter III. It is very suitable for "close-ups"—announcers, lecturers, debates, etc.

The high-intensity carbon arc, mask cut-out, scanning disc with holes in a spiral, wall with plate glass window, and studio with its equipment follow each other just as was indicated for L.D. television in Fig. 37. In the 30-line method the arc lamp and mask cut-out were opposite a side rim of the disc, and the scanning was done vertically. In H.D. work the scanning is done horizontally: the lamp and mask cut-out are therefore opposite the top rim (Fig. 73), so that the disc-holes will, in turn, sweep horizontally across the light beam.

For 180-line scanning a large disc is used provided with 180 holes arranged along the necessary spiral, and the mask cut-out is of such a size that there is never more than one hole active at any one time: one hole passes behind the mask at one side of the cut-out *just a little before* the next hole enters the cut-out from the other side (" just a little

before " provides that time interval necessary for a synchronising pulse to be sent at the end of each line). During one revolution there will be 180 horizontal journeys across the cut-out, the journeys being " edge to edge " owing to the spiral arrangement of the holes, and there will be therefore 180 horizontal journeys of the spot-light across the object televised, the spot-light journeys being likewise " edge to edge." The varying light reflected from the object falls on the cathodes of suitably placed photo-electric cells with the result that the latter give a corresponding varying current which, after amplification, is passed to the appropriate transmitter to modulate the *carrier wave on which the vision is sent out.* But all this has already been explained. The speed of the disc is 25 revolutions

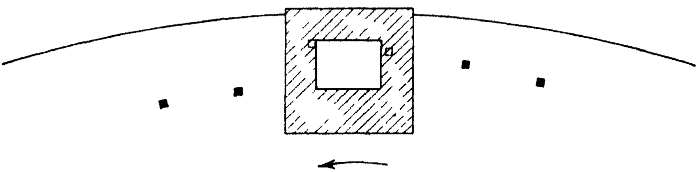


FIG. 73.

per second (25 pictures per second), *i.e.* 1500 revolutions per minute. In the case of these large high-speed discs it is usual to arrange that they revolve in a partially evacuated casing.

The necessary large number of holes in a single spiral presents a certain difficulty. Another method is to have two spirals of holes, 90 in each spiral. In such a case two holes one above the other—one belonging to one spiral and the other to the other spiral—will appear in the mask cut-out together, so that a shutter-device must be incorporated to cut off the beam from one hole while the hole of the other spiral is doing the scanning. The disc must go round twice to complete a scan of 180 lines, and as we still want 25 pictures per second the disc must run at twice

Photograph Courtesy of Baird Television Co

BAIRD'S TALKING-FILM SYSTEM OF TELEVISION WITH DISC SCANNING

The Telecine Disc Scanner, etc, used in the televising of ordinary cinema talking films

the speed, *i.e.* 3000 revolutions per minute instead of 1500. Similarly a 240-hole disc could have two spirals, 120 holes in each, the speed being again 3000 revolutions per minute.

Of course, more than two spirals can be used. Fernseh A.G. (Germany) use 4 spirals, 45 holes in each (180-line scanning), speed 6000 r.p.m. Baird now uses 4 spirals, 60 holes in each (240-line), speed 6000 r.p.m.

In Chapter III. we explained why " synchronising " was necessary, and referred to the short interval of time at the end of each scanning line when no spot-light was on the area scanned—one hole passing out of the light area an instant before the next hole came into it: and we further explained that during this interval a pulse or signal was generated at the sending end, superimposed on the picture signal, and filtered out, so to speak, at the receiving end to work the synchronising gear. For high definition work, a television transmitting apparatus should send out, in most cases, *two* sets of synchronising pulses, viz. one at the end of each scanning line (*i.e.* for 180-line scanning 180 pulses per picture or $180 \times 25 = 4500$ pulses per second) and another *distinct* one (say longer) at the end of each picture (25 per second). The former is referred to as the *high or line frequency synchronising pulse,* and the latter as the *low or picture frequency synchronising pulse.*

The synchronising pulses in the spot-light case we are now considering are produced as follows:—In our disc with 180 holes in a spiral there are 180 fine slits (*i.e.* in addition to the scanning holes). A lamp is placed at one side and a photo-electric cell at the other. As the disc rotates these slits come in turn into the beam from this lamp, light passes through to the cell, and the latter gives a pulse of current. By a proper positioning of the slits it can be arranged that these pulses are produced just at the right instant, *i.e.* at the end of each line, occupying the short period when no spot-light is on the area scanned. A similar procedure is adopted between complete scans or pictures. These

synchronising pulses, as already mentioned, are amplified and superimposed on the picture signal (Fig. 74), and subsequently are filtered out at the receiving end to actuate the synchronising devices there.

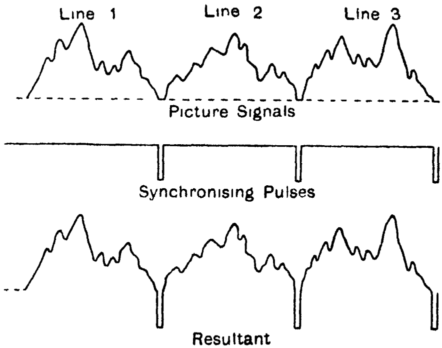


FIG. 74.

Microphones in the studio pick up the speech or music and convert it to a varying current which, after amplification, is passed to the transmitter which produces *the carrier on which the sound is sent out.* Incidentally, remember that in H.D. television the sound and the vision can be sent on *wave-lengths* that do not differ much from each other.

2. The Talking-Film System

In some respects the televising of a talking-film—the ordinary film used every day in the cinema, consisting of a series of complete photographs arranged one above the other with a " sound record " down one edge of the film—is easier than the televising of a living person, for there is more light to affect the photo-electric cell, and this certainly helps matters.

In Fig. 75 the lens A concentrates light from the arc lamp L on the film F, which is continuously moving downwards through the gate G from the film spool S at the top to another at the bottom. The separate pictures pass downwards through the gate G at the rate of 25 pictures per second. By means of the lenses B a real image of these pictures is projected on the top rim portion of a scanning disc D. As the disc rotates the holes will in

turn pass across the image—in other words the image formed on the upper portion of the disc will be scanned horizontally—and wherever the hole happens to be at any instant a certain amount of light *will pass through it,* the amount depending on the light and shade of the part of the image where the hole happens to be at that instant.

The disc differs from the scanning discs dealt with in previous pages in the fact that the holes are arranged

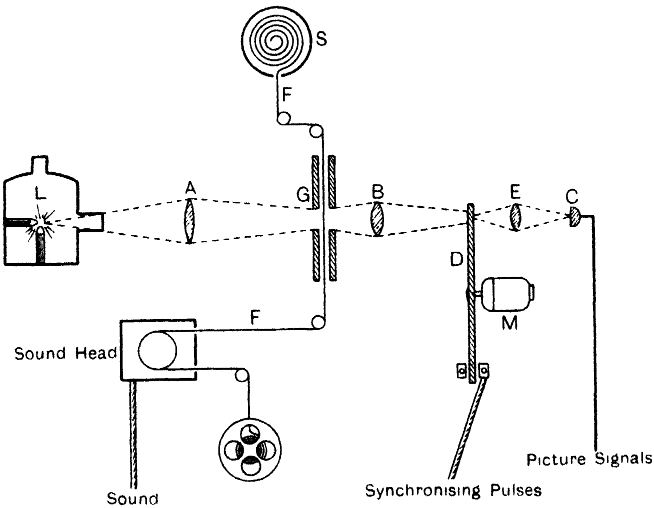


FIG. 75.

in a circle instead of in the usual spiral formation. As the holes are at equal distances from the centre of the disc the horizontal journey across the image which one hole makes will be in the same position as the horizontal journey made by any other hole. But it must be remembered that the film itself is moving downwards through the gate, so that the image at D is also continuously moving vertically. Thus when the first hole completes its journey across, the second hole begins its journey, but

during the first journey the image has moved vertically, so that the second hole's journey (although it occupies the same position as the first journey) is over another portion of the image. By a suitable adjustment of dimensions, speed, etc., it can be arranged that the image is properly scanned in a series of horizontal lines " edge to edge " just as the person or scene is scanned in the spot-light method.

The varying light coming through the holes—amounts depending on the light and shade of the various parts of the image and therefore of the film—is focused by the lenses E on the *single* photo-electric cell C, which in turn gives a corresponding varying current; and this after amplification, etc., is *caused to modulate the carrier wave on which the vision is transmitted.*

Note it is the light from L that *passes through* that is ultimately used on the cell, not the light *reflected from a person or scene* as in the preceding case.

And now for a few details. For 240-line scanning there are 120 holes in the large disc arranged on a circle, the angular separation between holes being 3°, and the disc rotates at the rate of 3000 revolutions per minute or 50 revolutions per second. In one revolution, *i.e.* in $\frac{1}{50}$ second, there will be 120 hole-journeys across the image, and in two complete revolutions, *i.e.* in $\frac{2}{50}$ or $\frac{1}{25}$ second there will be 240 journeys across. But the film moves downwards (and the image also moves) at the rate of 25 pictures per second, so that it takes $\frac{1}{25}$ second for one " image-picture " to pass across the mask cut-out, and in this time 240 journeys will have been made across it. Thus each complete " picture " is cut up into 240 horizontal strips as required in 240-line scanning. Similarly for 180-line scanning there are 90 holes in the disc, the angular separation between holes being 4°, and the disc speed is again 3000 revolutions per minute or 50 per second. In Baird's latest 240-line film scanning apparatus (the " Telecine ") his disc has 60 holes in a circle, and the speed is 6000 revolutions per minute.

The necessary synchronising pulses are produced in the same way as is indicated in the preceding spot-light method. In the 180 case, for example, the disc has 90 fine slits (in addition to the 90 holes), and a lamp is arranged at one side and a photo-electric cell at the other. By properly positioning the slits it is arranged that the resulting pulses occur at the correct instant, *i.e.* at the end of each line. A similar procedure is adopted between separate complete pictures, in this case a local 25-cycle impulse generator being used. These pulses, as already mentioned, are superimposed on the picture signal in their correct positions.

Again, in the talking-film there is, down the edge of the film, a series of lines of varying density which constitutes

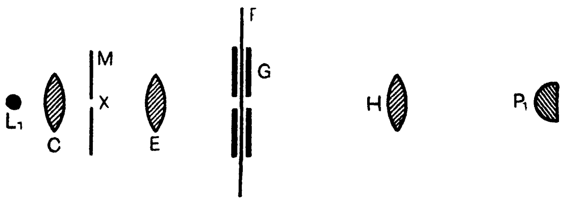


FIG. 76.

the sound record, *i.e.* the speech, etc., of the persons in the corresponding picture. Fig. 76 will show how this part of the film can be dealt with at the sending end.

In the figure, L_1 is a source of light, and C a lens which concentrates the light on a narrow slot at X in the mask M. The lens E is so placed that it focuses an image of the slot on the sound record on the edge of the film which is continuously passing through G. The light which passes through the sound record meets the lens H by which it is concentrated on a photo-electric cell P_1. Clearly a varying amount of light depending on the varying density of the sound record, and therefore upon the words originally spoken, falls upon P_1 which, in consequence, gives a corresponding varying current. This varying current after

being amplified, etc., is *caused to modulate the carrier wave on which the sound is transmitted.*

It will be noted (Fig. 75) that the film passes in turn through the vision part of the apparatus and the sound part of the apparatus. In the talking film, however, the sound record corresponding to any particular picture is not by the side of that picture but so far *ahead of it* so that sound and corresponding picture will be reproduced together.

Incidentally we mentioned that the cathode-ray tube is largely used as a *receiver* for television: it is described in Chapter VI. It can, however, also be used as a "scanner" of a film at the sending end. As will be seen in Chapter VI., a very narrow beam of electrons in the tube produces a small spot of light on the end of the tube where it strikes it, and the electron beam is so moved that the light spot "scans" the end of the tube in a series of horizontal journeys. By focusing the spot-light on a film which is continuously moving downwards, the film will be scanned by the horizontal movements of the spot. Fig. 77 gives a *rough* idea of the *general principle* but is not intended to be the *details* of a practical device: we merely mention it casually here—see later.

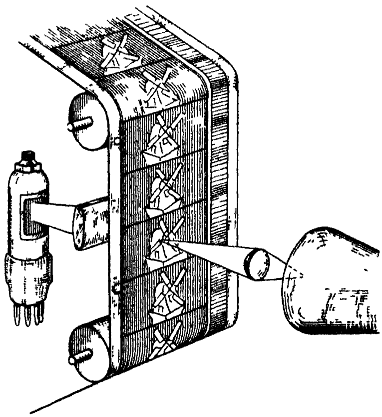


FIG. 77.

3. The Intermediate-Film System

We have seen that the Spot-light System *for actual objects*—or "subjects,"—although it has a definite place in any complete scheme of television, is best adapted for

close-ups. The Intermediate-Film System (developed by Baird), on the other hand, enables large scenes, indoor or outdoor, to be dealt with. Further, the apparatus can be carried by a small truck to the place of any important event which is to be televised. Finally the film can be dried and stored for transmission on future occasions by the film method already described. The undoubted success of the system is largely due to recent progress made in the cinema and photographic worlds—discoveries

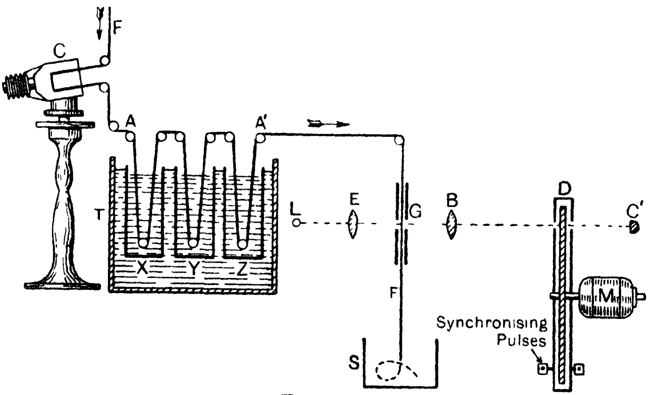


FIG. 78.
X, Y, Z = Developing, washing, and fixing tanks. L = Light source.
D = Scanning disc. M = Motor. C′ = Photo-electric cell.

in connection with rapid-acting emulsions, processing developers, and fixers, which enable excellent film negatives to be made and ready for scanning in a minimum of time —15 to 30 seconds. On this account it has been called for brevity *delayed* television: but the term is not a good one, for it creates a wrong impression in the minds of those who " do not know ": 30 seconds is surely not much of a delay, even in these speed-craze days.

The principle of the method will be gathered from Fig. 78. C is a cinematograph camera through which is

passing an unexposed film F coated with a specially rapid and sensitive emulsion, and the " scene " is photographed on the film—just as is done every day by the film people—25 exposures being made every second. At the same time microphones pick up the sounds and a sound record (a series of lines of varying density) is produced on the narrow strip down the edge of the film: this again is a procedure carried out every day in the film world, but as most people know less about this than photography, the method of producing sound records on cinema talking-films will be explained later.

From here the film passes over a driving sprocket A into a processing tank fitted with three compartments containing the necessary solutions for developing, washing, and fixing: the tank itself contains water which is maintained at a constant temperature (about 75° F.). From the tank the film, still wet, passes on through the gate G at the rate of 25 pictures per second, and here the television process begins exactly as described for the television of an ordinary talking-film in Art. 2: picture signals and synchronising pulses are produced by a scanning disc (holes in a circle) and photo-electric cells, and caused to modulate the carrier on which the vision is sent out, whilst at the same time the sound record down the film edge is converted to an electrical signal which is caused to modulate the carrier on which the sound is sent out—*all, in fact, exactly as in Art.* 2. The total time from the camera " shots " to the " television " is only 15 to 30 seconds.

There are a few additional points to be noted. The wet film after the scanning process usually passes into a storage tank, is dried, etc., and used for future transmissions by the film method of Art. 2. An alternative method, if a permanent record is not required, is to pass the film continuously through additional tanks in which (*a*) the present emulsion (and " pictures ") is washed off; (*b*) the film is re-emulsioned; (*c*) the film is dried; and then the film passes on again to the cinematograph camera for

further " shots." The film, in fact, is a sort of loop or endless band passing continuously through the apparatus, and this results, of course, in film economy.

It should be observed that the pictures on the film are " negatives," whilst in the talking-film method previously described commercial films are used on which the prints are " positive ": and it will be remembered that a finished photograph and its negative differ from each other in the sense that what is dark on one is light on the other. The picture signals from the intermediate film apparatus will therefore be anti-phase to those given by the same scanning apparatus, etc., operating on an ordinary talking-film: in other words, if the talking-film gave a correct picture, the other would give a negative picture. This is easily corrected, however: the television engineers at the station need simply add to (or take from) the photo cell amplifier of the intermediate-film apparatus one stage of resistance-capacity coupling (see Art. 11, Chapter III.).

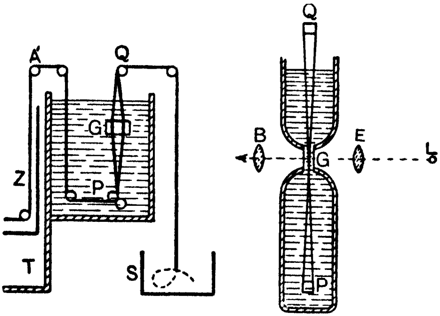


FIG 79.

Fig. 78 is, of course, only diagrammatic in order to show the principle of the method: in actual practice the various parts are differently disposed relatively to each other from that shown in the figure in order to secure compactness and convenience. For example, it is usual for the film in going through G to be twisted through 90° (Fig. 79) so that the scanning devices (arc, lenses, photo cells) may be in a line at right angles to the page of this book: but this and other points are details. Note that the film

is still in water while it is being scanned: to avoid errors due to drops of water sticking to it a film must be either " evenly wet " or " thoroughly dry " for scanning.

And now a word or two about the method of obtaining a sound record down the edge of a talking-film—whether it be Elstree, Hollywood, or Television. Fig. 80 will make the general idea clear. The microphone M picks up the sounds and converts them into a corresponding varying current. This is amplified and passed through a gas-discharge tube L, so that the illumination of L varies with the varying current just as the neon or other gas-discharge lamp does in the low definition television receiver described in Chapter III. By means of the lenses shown the varying light is projected through a slit on to the narrow strip

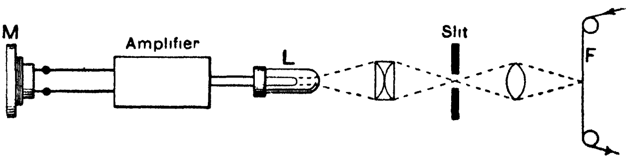


FIG. 80.

down the edge of the undeveloped film F which is moving downwards: thus a series of lines of varying density is formed which depends on the varying light and is therefore a " copy " of the original sound produced in front of M.

4. The Electron-Image Camera System

The systems we have dealt with—except Fig. 77—have involved mechanical methods of scanning—revolving discs and drums driven by motors. There are, however, systems based entirely on electrical scanning—methods which possess many advantages over mechanical devices. Electrons can be moved about *instantaneously* and practically *without noise*—and noise is an important factor especially when microphones are in the vicinity. And these electrical methods can be used for both indoor and outdoor extended

scenes and for films. They are spoken of in general as *electron-scanners*. Some television workers contend that they will, in time, supersede mechanical arrangements: it is perhaps more likely, however, that all the methods described, and may-be others, will be used, according to their suitability for various purposes, in providing a complete television broadcast service.

One of these systems which has been developed by Baird and uses what may be briefly called an "electron-image camera," is based on certain inventions by Farnsworth in America. C. E. C. Roberts, in this country, also worked on similar lines, but his British Patent is dated 1928 whilst Farnsworth's American Patent is dated 1927, and in any case, many refinements are due to Farnsworth: hence it is that his name so constantly appears in connection with the general scheme.

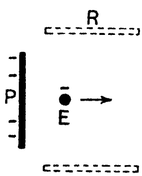
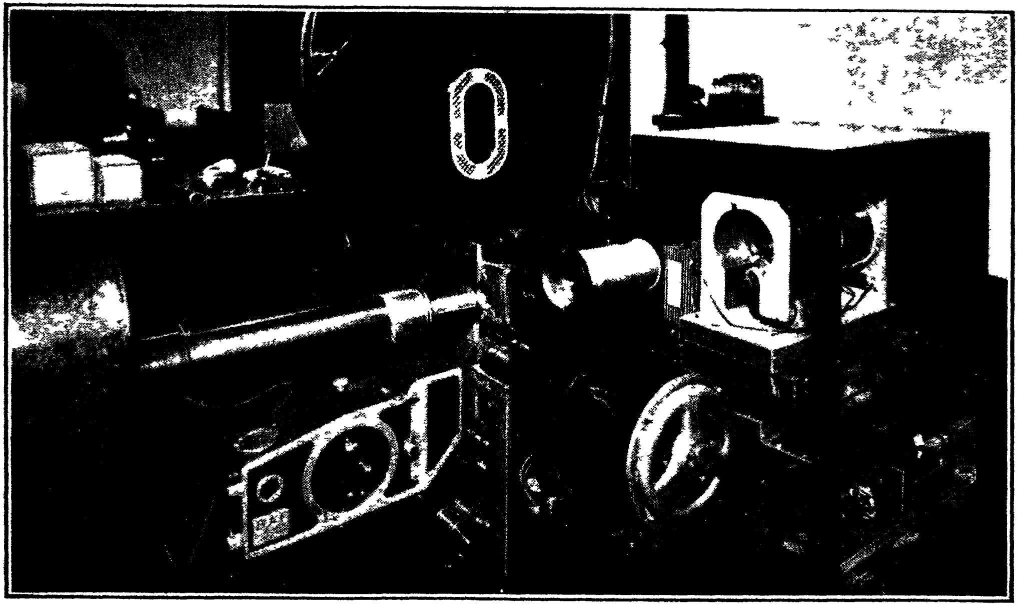


FIG. 81.

The Farnsworth experiments produced two devices, viz. the *Image Dissector* and the *Electron Multiplier*, which are combined in one "camera": the former does the scanning and the latter the amplification of the resulting electrical signals, *i.e.* the picture signals. You will best understand the general principles if we describe these two devices separately and then combine the two. But there are one or two facts, well known to students of Electricity, which must first be briefly referred to.

(1) MOVING ELECTRONS ABOUT. Suppose E (Fig. 81) is a negatively charged body free to move, and P and Q two metal plates. If P be charged negatively and Q positively, E will move off to the right, being attracted by Q and repelled by P. If P be now quickly made positive and Q negative, E will move back again to the left. It is clear that by constantly varying the potentials of the plates P and Q at a suitable rate we could keep our negatively



Photograph Courtesy of Baird Television Co

BAIRD'S ELECTRON SCANNER SYSTEM OF TELEVISION

The Electron Scanner when used in connection with the televising of talking films. This can be employed for a definition of from 100 to 500 lines. The image dissector for the electron scanning is seen on the right. There are no mechanically moving parts other than the moving film mechanism.

charged body E moving to and fro in a horizontal direction. And we might vary the rate at which E moves—we might make it go faster in one direction than in the other direction —by suitably varying the rate at which the potentials of P and Q change.

Again, by means of two plates R and S, one above and one below, we could cause E to move up and down between the plates. And by using the four plates together we could impart to E a horizontal and a vertical motion at the same time, the actual motion of E at any instant depending on the resultant of the electric forces acting on it at that instant.

In a somewhat similar way *electrons* (negative) can be moved about by the varying electric forces due to metal plates suitably placed, the plates having varying potentials given to them.

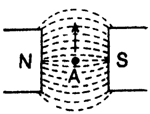


FIG. 82.

Again, it is well known that if a wire carrying a current be suitably placed in a magnetic field (due either to magnets or other currents in coils of wire) it will move if it is free to do so, the direction of its motion depending on the direction of the current and of the magnetic field. But a current in a wire is simply electrons moving along in the wire: hence we would expect that any stream of electrons could be deflected to left or right or up or down by setting up magnetic fields and suitably arranging the fields. It can be done, and it is done in the Farnsworth devices (and in many other devices).

There is just one point more to note, however. In Fig. 81 any electron E would tend to move *along* the lines of force in the *electric* field between the two charged plates. In Fig. 82 if A is a wire going "into the paper" and carrying a current, the moving electrons constituting the current also going "into the paper," the wire would tend to move in the direction of the arrow, *i.e. at right angles* to the lines of force in the *magnetic* field due to the magnet

poles (or currents in coils) N., S. We merely state this so that you may note the difference: it is not important at this stage.

(2) A SAW-TOOTH MOTION.—Suppose we have a pendulum, the bob of which consists of a hollow vessel filled with sand, and that the vessel has a hole at the bottom through which the sand steadily trickles out. Start the pendulum swinging to and fro above a sheet of paper and gradually, and at a uniform rate, draw the paper along horizontally. The trickling sand will trace a curve on the paper—a "motion-time" curve for the pendulum. Fig. 83 shows the kind of curve obtained. It is known as a simple *sine curve*, and is obtained with most *natural* types of oscillations whether mechanical or electrical: the alternating current curve given in Fig. 11 is of this character.

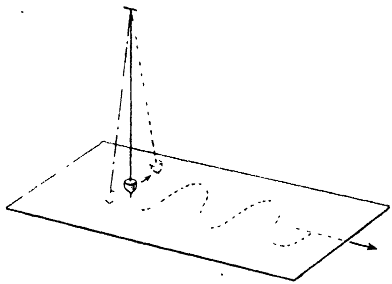


FIG. 83.

Now suppose that in some way we could make our pendulum swing *steadily and relatively slowly* in one direction, say from left to right, and then swing back *very rapidly* from right to left. Fig. 84 would evidently be the kind of curve the sand would trace, where AB, CD, and EF represent the steady and relatively slow motions from left to right, and BC, DE, and FG the very quick returns from right to left. Any "variation" of this kind—a relatively slow "change" in one direction followed

FIG. 84

by a quick return or kick-back to the starting condition —whether it is a mechanical motion, or a variation of current strength, or a variation of potential, etc., is called a "saw-tooth variation" because the curve is rather similar to the teeth of a saw.

When you consider the matter carefully you will see that if we scan a scene by, say, a spot-light, we really require a saw-tooth movement of the spot, and therefore a saw-tooth variation of some sort to bring it about. Suppose ABEF is the light area or scene to be scanned by a single spot-light. We will assume the usual 240 lines and 25 pictures per second. The spot starts at A and moves uniformly along from A to B in $\frac{1}{6000}$ second. It must then be rapidly triggered back (dotted line) from B to C in order to begin its uniform trace of the second line from C to D, this line being below and edge to edge with the first line. This continues for $\frac{1}{25}$ second by which time the spot will be at F, having completed its 240 line journeys. It must then be rapidly triggered back to A to begin its second scan.

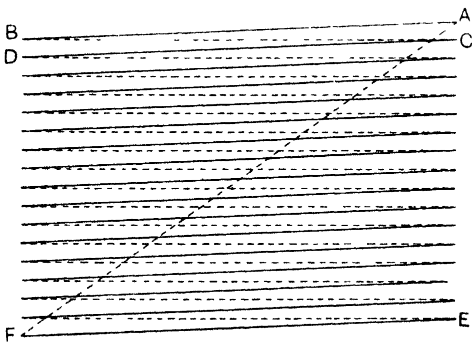


FIG. 85.

Note that there are two saw-tooth motions here. In one the spot moves uniformly from right to left in $\frac{1}{6000}$ second and is at once triggered back from left to right. In the other the spot moves uniformly downwards from top to bottom in $\frac{1}{25}$ second and is at once triggered back from bottom to top. Remember that these two saw-tooth

variations are occurring together: that is why the scanning lines slope downwards towards the left, for while the spot is moving along it is being gradually moved downwards (for simplicity we are assuming *instantaneous* fly-backs).

We have used a single moving spot-light in our illustration above in order to make the idea simple. In the electron scanners used in television which we are about to consider it is electrons which are moved about (either by plates at varying potentials or by coils with varying currents, as explained above): the movements of the scanning electrons must be saw-tooth and therefore the *causes* of the movements, *i.e.* the varying potentials given to the plates or the varying currents given to the coils, must both be of the saw-tooth character.

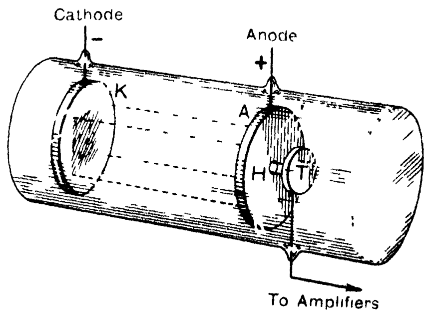


FIG. 86

We can now consider the construction and action of the Image Dissector and Electron Multiplier used in television.

(3) THE IMAGE DISSECTOR.—Imagine a glass cylinder (Fig. 86) at one end of which is a circular cathode K (*i.e.* it is joined to, say, the negative pole of a battery). This cathode is coated on its inner surface with a layer of photo-electric material—a material which gives off electrons when light falls on it just as does the cathode of a photo-electric cell. Imagine also that at the other end of the tube we have an anode A (*i.e.* it is at a positive potential relative to the cathode) pierced with a small hole H, and that just behind this hole we have a conducting target or collector T. The cylinder is exhausted.

An image of the scene to be televised is focused, by photographic lenses in the usual way, on the photo-electric surface of K. The result is that the surface of K ejects electrons, the number ejected from any part depending on the amount of light producing that part of the image: if one part of the image has twice the light that another part has it will give off twice the number of electrons. In other words, electrons are given off in proportion to the light and shade of the image. We will assume for the present that all the electrons are given off from the cathode at right angles to its surface.

As the anode A is at a positive potential the (negative) electrons will be attracted towards it, so that we have what we might call an " electron beam " passing along the tube. Moreover the electrons will keep their proper formation all the way along the beam. At any section of the beam we will have an " electron image "—an image made up of electrons—which bears a true relation to the light and shade of the image at K, and therefore to the scene televised. You can't see this image made up of electrons, *but it is there* nevertheless.

Now consider the electron image in the beam at A. A particular part of the image will fall at the hole H and the electrons of that part will pass through and be received by the collector T. If another part of the image fell at H a different number of electrons would pass through to T. It is clear, then, that if we could move that hole horizontally across the electron image, then *very quickly* get it back again, then move it horizontally across again, this second journey being edge to edge with the first one, and so on, the varying numbers of electrons passing through H to T would form our " picture signal " which could be taken from T to amplifiers, and finally caused to modulate the carrier wave on which the vision is sent out. In fact we want to scan the electron image at A by 240 scanning lines, make them edge to edge by gradually moving the scans vertically, and we want to keep on doing it at the rate of

25 complete scans or pictures per second. And both horizontal and vertical movements must be saw-tooth in character: there must be (240 × 25), *i.e.* 6000-line journeys across per second, each followed by a rapid kick-back, and at the same time there must be 25 vertical movements per second, each complete vertical movement being followed by a rapid kick-back to the starting point.

In practice this is what is done, but instead of moving the hole over the electron image we move the image over the hole: this will give the same result.

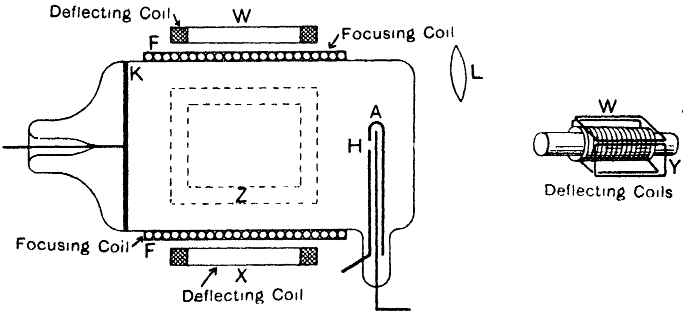


FIG. 87.

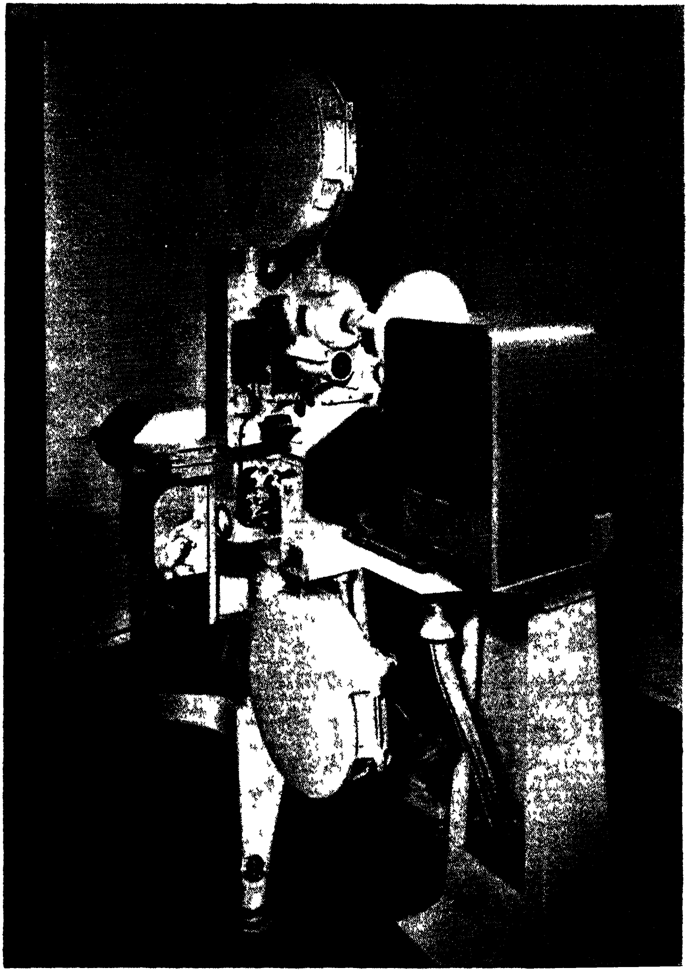
And now for a few details (see Fig. 87). The image of the scene (in this particular pattern) is focused on K from the front by the usual photographic lenses arrangement indicated roughly by L. The cathode is of pure silver, and the photo-electric coating on it is caesium oxide. At A is the anode (pierced with a hole) and the target collector. The inside of the tube is coated with a thin film of nickel (this really forms a very high resistance connection between anode and cathode). The tube is exhausted.

As the caesium coating on K really consists of very tiny crystals the electrons are not all given off at right angles to K, as we supposed them to be, but at slightly different angles. The result of this would be that the electrons in

the beam would be more or less dispersed by the time they reached the anode A, and the electron image there would not be a sharply-defined image. To overcome this spreading and blurring the attractive effect of the positive anode on the negative electrons is made big, and a focusing coil F is used to focus a sharp electron image exactly at the anode. This focusing coil is a coil of wire (round the apparatus) joined to a battery through a variable resistance. It produces a magnetic field down the tube, and by a suitable adjustment of this field the electrons can be so moved that they are focused, and a perfect electron image produced at the anode just where it is required. We shall refer to this again presently.

The electron image is now scanned by moving the whole electron beam and image horizontally and at the same time vertically (to get the horizontal scan-lines edge to edge) in front of the hole H. At the end of the first horizontal journey the whole image is rapidly triggered back ready for the next journey: during the first journey the whole image has also made a slight vertical movement so that the second horizontal journey is adjacent to the first one. When the 240 horizontal lines have been completed and the image completely scanned, the whole image is triggered back to the original position and the scanning repeated. Note that the operations—horizontal and vertical—are both saw-tooth.

Farnsworth brings about that horizontal and vertical movement of the electron beam (and image) across the hole by means of magnetic fields due to currents in two pairs of "deflecting coils" on opposite sides of the tube: the current in one pair of coils causes the horizontal movements and the current in the other pair causes the vertical movements but, of course, both pairs are acting together. One pair of coils W, X is above and below, and the other pair Y, Z is in front and behind (the Y coil is not shown and the Z coil is shown dotted—but see small figure). The current in each pair is given the necessary saw-tooth wave



Courtesy of the Marconi Wireless Telegraph Co.

THE MARCONI E M I. "EMITRON" CAMERA SYSTEM OF TELEVISION.

Shows the Film Projector and the Camera used in the televising of Films.

form to bring about its saw-tooth movement of the image, *i.e.* in each pair of coils we have a steady current increase followed by a sudden drop. This saw-tooth variation of the currents in the deflecting coils is easily produced by a simple valve circuit, but we need not go into details of this. The same valve circuits can be made to give the necessary synchronising pulses, viz. one at the end of each line, the other at the end of each picture.

Just a remark here: it is the coils with a horizontal field which cause the vertical movement, and the coils with the vertical field which cause the horizontal movement. See page 112 and *think* about it.

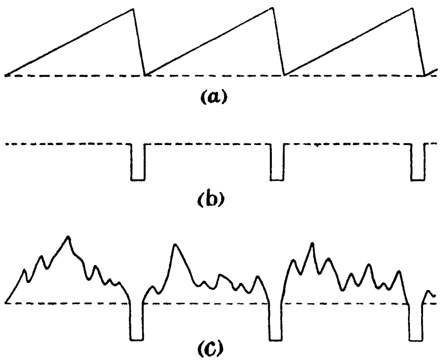


FIG. 88.

(*a*) = Saw-tooth current variation in deflecting coils. (*b*) = Synchronising pulses. (*c*) = Resultant signal.

Note that if a film is being televised (an optical image of the film pictures being projected on to K) only one pair of deflecting coils is necessary, viz. the pair producing the horizontal movement, for the film itself will be moving downwards at 25 pictures per second and the electron image at A will have the necessary vertical motion.

As already explained, as the electron image does its movements, varying numbers of electrons pass through the hole giving varying impulses to the target corresponding to the light and shade of the scene televised. These together with the synchronising pulses pass to the amplifying systems and to the transmitter to modulate

the carrier wave on which the vision is sent out. Fig. 88 roughly indicates the points we have mentioned so far as the horizontal movements are concerned.

Just one word more about that focusing coil which is necessary (as the electrons do not all leave K at right angles) in order to get a well defined electron image focused at A. It can be shown that if two or more electrons leave the same point on K at different angles they will travel in different helical paths down the magnetic field due to the focusing coil, but by a proper adjustment of the field strength it can be arranged that *they all arrive together* at A. This applies also to electrons from other points on K, so that the net result is a well defined electron image at A where it is wanted.

(4) THE ELECTRON MULTIPLIER. The dissector alone is quite satisfactory for film television, but for other work Farnsworth attaches to the dissector apparatus (as a kind of second chamber or annexe) another piece of apparatus known as the electron multiplier. This really multiplies the number of electrons which come through the hole from each part of the electron image and therefore produces stronger picture signals.

Under certain conditions when an electron violently bombards a conducting surface it may so agitate the electrons in the atoms of the conductor that some are ejected. In such cases the bombarding electron is usually spoken of as the primary electron, and the electrons it causes to be ejected, the secondary electrons. The number of secondary electrons emitted naturally depends on the speed at which the primary electron is moving, and also on the kind of surface the primary hits. Caesium has been found to be one of the best elements for the present purpose: it gives out 5 or 6 electrons per hit.

Now suppose we have two plates P and Q facing each other, their inner surfaces being coated with caesium. Suppose P is provided with a small hole in the centre, and

that, in some way or other, we can drive electrons through that hole at a big initial velocity so that they travel along and strike Q, ejecting secondary electrons from the caesium surface. Suppose now that these secondary electrons could be made to travel back to P, striking it and ejecting more electrons, and suppose this to and fro movement could be made to continue for a time. If we shoot one electron only through the hole then, assuming an electron causes 6 electrons to be ejected when it strikes, it is clear that after five impacts only the amplification would be more than 9000. Big amplifications are therefore possible if this principle can be applied in practice. It is done in the electron multiplier.

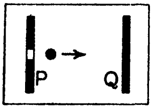


FIG 89

The multiplier consists of a cylindrical glass vessel which is exhausted and contains two disc cathodes P and Q of nickel parallel to each other as shown in Fig. 90: the inner surfaces of P and Q are coated with caesium. This tube is built on to the image dissector tube as a kind of second chamber. The target arrangement of the dissector is dispensed with, and P is provided with a small hole through which pass the electrons from the scanned electron image in the dissector tube. A is a ring anode maintained at a high potential. The comparatively weak stream of electrons

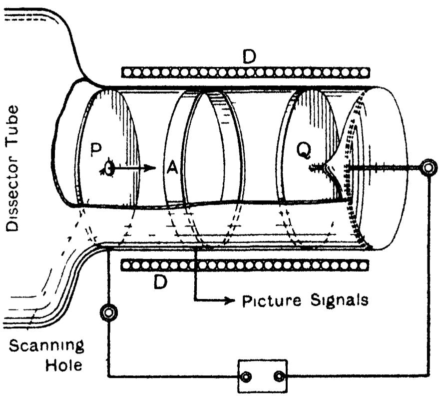


FIG. 90.

coming through the hole from the dissector compartment are attracted towards the positive ring anode. A strong magnetic field due to a current carrying-coil D wound on the tube prevents these electrons from actually striking the anode, and compels them to pass on down the centre of the tube towards Q. When they strike the caesium surface of Q secondary electrons are emitted. These in turn are attracted towards the positive ring anode, but again are caused to pass on, striking P and liberating still more secondary electrons.

Unless something further be done, however, electrons passing through A towards Q might not reach Q owing to the pull-back of the positive anode A. To keep the electrons travelling the full distance between P and Q an oscillating current circuit with a frequency of about 50 million cycles is applied to the plates P and Q, and this is adjusted so that the electrons pass the full length from P to Q or Q to P during one half cycle of this oscillating circuit, *i.e.* they go in one direction during the "up loop" (as we called it in Chapter II.), and in the other direction during the down loop.

Since at each traverse there is a big increase in the number of electrons, it will be evident that if the to and fro movement is allowed to go on continually a kind of saturation condition will be reached, and we will no longer get a true copy of our input from the dissector tube. Hence after a certain number of journeys the action is stopped and the signal taken off at the anode as shown: this will be a true but magnified or amplified copy of the weak electron stream from the dissector tube which began the magnifying process. This stopping of the action after a certain number of journeys is done by putting into the circuit an "interrupting frequency" which checks the action at intervals as required; but you need not worry about the details of this. Incidentally, there are other methods of bringing about this result, but the method referred to is the one most frequently employed.

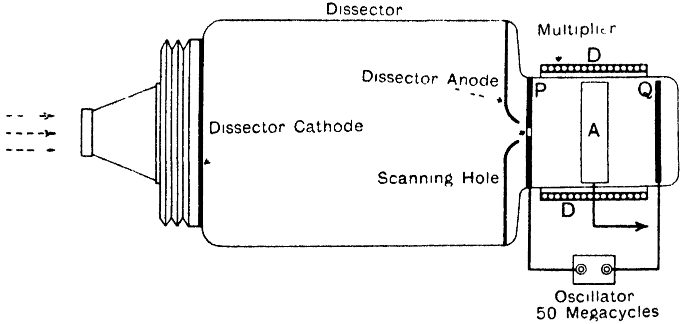


FIG. 91

The output-signal from the electron multiplier is now passed to the usual apparatus to modulate the carrier wave on which the vision is sent out.

Figs. 91, 92 show the complete arrangement—dissector and multiplier combined in a single camera structure which can be easily moved about and used for indoor or outdoor purposes. In this complete camera the cathode of the dissector tube consists of a translucent film of oxide of silver deposited on the glass end of the tube, and on the film is the caesium: the image of the scene to be televised is focused on the outside of the tube end as shown, and, of course, the action is just the same as previously explained.

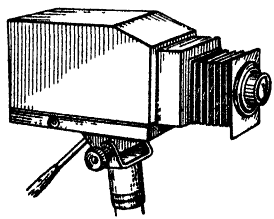


FIG. 92.
The "Dissector-Multiplier" Camera.

In the photo-electric cell we saw that the light caused electrons to be ejected from the cathode, and these were attracted to the anode, thus giving a current in the circuit: we saw, too, that the current was small and had to be considerably amplified. It is clear, however, that if the electrons were caused to first strike another sensitive

cathode, and so on, secondary electrons would appear, and great amplification would result. This principle has recently been applied in practice.

5. The Iconoscope Camera System

This is another system in which electron scanning is used. It also is of American origin, having been devised by Zworykin in that country, and it has been in regular use for some time by the R. C. A. Victor Company. The Marconi E.M.I. have developed the idea in this country in their "emitron camera."

The iconoscope itself consists in the first place of a modified form of what has come to be called a "cathode-ray tube," and which is used in television receivers. The cathode-ray tube is fully explained in the next chapter dealing with H.D. television reception, so that this part of the construction and action of the iconoscope will only be briefly referred to here.

If you recall the diode valve for a moment (Fig. 25) you will remember that at one end there was a filament cathode, and at the other end a plate anode (the plate was joined to the +ve and the filament to the —ve pole of the high tension battery), and when the filament was heated it gave off electrons which were attracted towards the anode. One portion of the iconoscope acts somewhat similarly.

The iconoscope consists of an evacuated glass vessel as shown in Fig. 93, at the extreme narrow end of which is the cathode which is heated. In front of the cathode is an anode (or two) each pierced with a hole at the centre and maintained, of course, at a positive potential. The electrons given off by the cathode are attracted by, and accelerated towards, the anode, so that we have a very narrow beam or stream of electrons shooting through the anode holes and going straight on into the wider part of the tube. It is this narrow beam or stream of electrons which is used to do the "scanning" operations. Of course there are many refinements in the construction of

this part of the apparatus to ensure a very narrow intense electron beam passing right along the axis of the tube into the larger end, but we will come to these presently.

Situated in the wide portion of the tube is a specially constructed plate-electrode M on which an optical image of the scene (outdoor or indoor) to be televised is focused by photographic lenses in the usual way. M consists of a thin sheet of mica (mica is an *insulator*) backed by a sheet of metal known as the *signal plate* (you will see why in a moment). The front surface of the mica is first sprayed

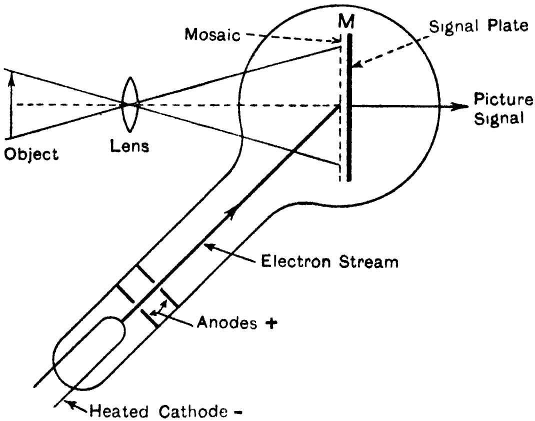


FIG. 93.

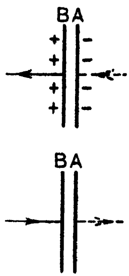


FIG. 94.

with silver oxide powder which is then heated and reduced to silver in the form of *tiny* globules: these are next oxodised so that they are insulated from each other, and then they are given a coating of caesium. Thus the front of the mica sheet is a " mosaic " of a tremendous number of tiny silver globules all insulated from each other, and each made sensitive to light, like the cathode of a photo-electric cell, by the coating of caesium. The iconoscope, in fact, may be said to be a combination of a cathode-ray tube and a multitude of photo-electric cells.

A little digression on a condenser.—Two metal plates A and B, separated by a very thin but good insulator, form, as you know, a condenser (Fig. 94). Suppose by some means or other we drag electrons out of B in the direction of the arrow. This leaves B with a deficit of electrons, *i.e.* a surplus of positive ions, or in other words, positively charged. Hence B, acting through the mica, attracts electrons (negative) towards the inner surface of A as shown by the dotted arrow, and A becomes negatively charged, *i.e.* has an excess of electrons: and moreover, in practice, the flow of electrons out of B is equal to the flow into A. The condenser in this condition is said to be "charged." Again, if B be "discharged" by passing electrons to it to make up its deficit of electrons (or to neutralise its positive charge), A becomes discharged by an equal number of electrons flowing out of it, thus getting rid of its excess electrons. The point to note is that whatever "action" happens on the B side it is immediately and exactly copied by the A side.

To continue with the iconoscope. Notice that *each* silver globule forms, with the signal plate behind and the mica between, a small condenser, so that M really consists of a large number of tiny condensers—millions of them—all insulated from each other (the back plate is, of course, common to all): and moreover *each* is capable of operating in the same way as a photo-electric cell owing to the coating of caesium, *i.e.* electrons are given off when light falls on it. When therefore an optical image of the scene to be televised is projected on M each photo-cell element of the surface ejects electrons according to the light and shade of that part of the image which falls on it, and each tiny condenser is therefore "charged" accordingly. What we now have, then, is a large number of tiny condensers each one of which is charged, the charge on each depending on the light and shade of the particular part of the image falling on it—the more the light at any

point the greater the charge of the tiny condenser there. Put another way, we have a " picture " on M made up of electric " charges," the charge at any point corresponding to the optical image at that point.

Now turn to the electron beam coming up from the cathode at the extreme narrow end of the tube. This electron beam is caused to scan the surface of M in the usual way, *i.e.* horizontally (240 lines in a complete scan with a rapid kick-back at the end of each line), and at the same time vertically (25 complete vertical movements per second with a rapid kick-back at the end of each). In fact the narrow electron beam is moved over the surface of M just as the electron-image beam was moved over the hole in the image dissector, both movements being again saw-tooth. And it is done in the same way. Two pairs of coils are situated near the neck of the bulb, one pair being above and below and the other pair in front and behind (Fig. 95): one pair is supplied with the necessary saw-tooth current variation to bring about the saw-tooth horizontal movement of the electron beam, and the other pair is supplied with the necessary current variation to bring about the saw-tooth vertical movement of the beam.

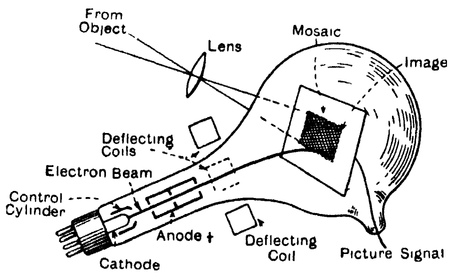


FIG. 95.

Consider then the scanning electron beam coming for an instant on one of the tiny condenser elements, and remember that the charge on the element depends on the light and shade of the image there. Electrons (negative) pass from the beam into the condenser, completely discharging it, and consequently an equal current impulse appears at the

signal plate behind. This happens with each element in turn as the electron beam scans the surface of M. Thus during the scanning we get a varying current in the signal plate circuit, the current at any instant depending on the charge on the tiny condenser which the electron beam happens to be discharging at that instant, which again depends on the light and shade of the part of the image there. In short, as the image of the scene at M is scanned by the electron beam we get a corresponding current picture signal in the signal plate circuit: this picture signal is passed to amplifiers, etc., to modulate the carrier wave on which the vision is sent out.

A more scientific and exact description of the action of the iconoscope can be given if variations of *potential* are considered but beginners find this more difficult to follow, and the above answers our present purpose. Moreover there are one or two "difficulties" which should be considered, *e.g.* the possible emission of secondary electrons when the electron beam is scanning, the possibility of more electrons entering a condenser from the beam than is required to exactly discharge: but these problems are beyond the scope of this book.

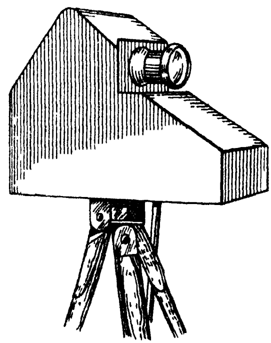


FIG. 96
The "Iconoscope" Camera as used for studio work

A few more details of the actual apparatus will be gathered from Fig. 95. We require an *intense, narrow* beam passing right up the axis of the tube through the anode holes: a long tube-anode is used with apertures as shown, and a controlling cylinder (negatively charged) is fitted near the cathode to repel the electrons to a narrow beam along the axis. The inner surface of the neck of the tube is metal coated (silver) to form a further anode. Note that

the image is on the mosaic all the time so that each element builds up its charge again as soon as the electron beam passes it: this fact leads to increased strength of signals. The synchronising pulses can be produced and sent out in their correct position (end of each line and end of each scan) as in the preceding method. The R. C. A. Victor Co. in their iconoscope system generate the synchronising pulses in a somewhat similar manner to that indicated on page 100. A disc is used perforated with 240 holes and rotated at 25 revolutions per second. A lamp is at one side and a photo cell at the other. The current pulses from the cell (240 per revolution) are amplified and superimposed on the picture signal in the correct position: at the same time they are passed to the iconoscope to control the deflecting circuits.

Since the electron beam meets the mosaic in a slanting direction the scanned area would not be rectangular—the top scanning line would be longer than the bottom scanning line: this is corrected, however, by a slight modification of the saw-tooth variation of current given to the deflecting coils.

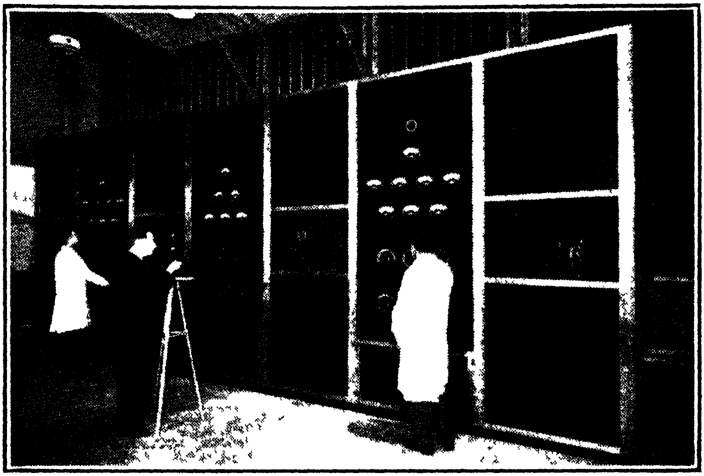
The whole apparatus including the photographic lenses, etc., is contained in a single camera structure much the same as the ordinary cinematograph camera, and is easily transported from one place to another for indoor or outdoor work. (Fig. 96.)

All the preceding systems have proved highly successful in practice, but great advances have also been made with one or two other methods. A short account of these is given later.

6. Interlaced Scanning

We referred to "flicker" on page 82. Flicker is practically absent in H.D. television reception (25 pictures per second) unless the "brightness" of the picture is very much increased, and then it is only slight even if it is present at all.

It was early suggested that a system of *interlaced scanning*, as it is called, should be adopted: in this, lines 1, 3, 5, 7, etc., would first be scanned, and then the intermediate ones, 2, 4, 6, 8, and so on. Another suggestion is to use a fluorescent material for the screen which retains the light at any point for a short interval after the " spot " has left it. Research is being carried on in both these directions.



ULTRA-SHORT WAVE RADIO TRANSMITTER

Baird's 10KW Radio Transmitter at his Experimental Station used for sending out television to Greater London and the Home Counties

Even looking at the matter in a very elementary way you will see why interlacing tends to reduce flicker. In ordinary scanning the " picture " is covered completely in $\frac{1}{25}$ second by 240 lines. In interlacing we sweep over the surface in $\frac{1}{50}$ second with 120 lines (although there are narrow spaces between them), and then we sweep over the surface again in $\frac{1}{50}$ second with 120 lines in the previous empty spaces. The missing spaces in each sweep are only the width of a line, and the eye does not perceive them

but gets an impression as of a complete " frame " *repeated* 50 *times per second.*

Both Baird and E.M.I. have experimented with interlacing. The E.M.I. are using 405 lines (there is a reason for this *odd* number), each frame scan being 202½ lines. The general idea is shown in Fig. 97 where 11 lines, 5½ in each frame scan, are indicated. Starting at A the firm lines are traced ending at F. The second scan of the dotted lines begins at A′ and ends at F′. The point A′ is half a line from A so there are 5½ lines in each scan. Baird, however, favours 240-line ordinary scanning under present conditions. Discs for interlaced scanning would have to be provided with two sets of holes: it is easy to arrange the scanning controls of electron scanners for interlacing.

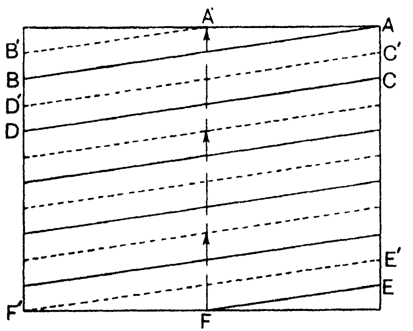


FIG. 97.
Principle of interlacing. The "fly-backs" between lines are not shown.

7. The "Lighting" of a Scene

At the theatre we sometimes have a scene in which the *general illumination* is low (a twilight scene) and sometimes one in which it is high (a sunlit scene). For realistic television some factor must therefore be sent out which depends on this *general* illumination. In L.D. reception we have had a definite brightness for our screens at the beginning, and *have merely had changes of this due to the relative lights reflected from different parts of the object televised.* In the new H.D. television an indication of the general illumination is, however, transmitted. One method is this: extra scene illumination, for example, will increase the D.C. output of the photo-electric cells, and the *carrier strength* can be

increased accordingly; this D.C. component effect will thus show itself in the television signal as well as the usual picture variations. At the receiver this effect can be used on the modulating arrangements to give corresponding *general* illuminations on the screen.

8. "Sending Out" and "Simultaneous Broadcasts"

We have seen that reception of television is limited to distances of 30-40 miles from the station (although greater distances have been covered). This means that several stations are necessary if the whole country is to be catered for.

In sound broadcasting a single programme from one studio is often " sent out " by several stations in different parts of the country. In such cases the current variations of the microphone in the studio are usually sent (after amplification) along land lines to the various stations where they are ultimately caused to modulate the carrier waves of these stations: thus the same programme is broadcast simultaneously on different wave-lengths by different and widely separated stations. Unfortunately, ordinary cable will not handle the big frequencies employed in H.D. television. Recently, however, a cable has been manufactured which can transmit television signals up to a distance of about 100 miles, and, doubtless, even further improvements in manufacture will follow. The trouble at present is its cost. However, it certainly does point to the possibility of simultaneous broadcasts in television.

Sound broadcasting also makes use of the " radio relay system." One plan is to send out a programme on *short waves*, which is received by a special receiving system at another station and then broadcast on that station's carrier. A somewhat similar device might be used in television: an outdoor event, say, might be televised on the spot, and the signals sent straight (directional transmission) to the transmitting station on *micro-waves* (·15–1·5 metres) from whence they could be broadcast as usual. But again range difficulties arise.

CHAPTER VI

AT THE RECEIVING END—HIGH DEFINITION TELEVISION

IN Chapter III. we described the two main types of television receivers which have been used during the last few years for reception in the home of the low definition television broadcasts, viz. the scanning disc and the mirror drum—both mechanical, driven by motors. Other methods have been used, and some of these will be given later, but discs and drums have formed the majority. We come now to the receiving end in high definition television, and here, as at the sending end of H.D., we encounter both mechanical and purely electrical devices. In this case of reception, however, there seems little doubt but that the electrical method, which employs what is called a *cathode-ray tube,* is best adapted for the purpose. *The tube can be used for any number of scanning lines* (L.D. or H.D.), and elaborate and searching tests have proved it to be *the* piece of apparatus best suited for H.D. reception: it is used in practically all the television receivers now on the market, or in course of construction, to take the B.B.C. present high definition broadcast service. Time alone will show whether this is to be the case permanently or whether the advocates of mechanical (*i.e.* mechanical *plus* electrical *plus* optical) will progress sufficiently in their research to supplant it with their devices.

1. Looking Backwards—for a Moment

Before considering the actual cathode-ray tube for television it is interesting and instructive to glance back to the early experiments—over seventy years ago—whereby the so-called " cathode rays " were first discovered.

It is well known that air and other gases under normal conditions are insulators: unless the electric pressure or potential difference is very high even a small air-gap in a circuit stops a current from flowing. If the *gas pressure* be reduced, however, the gas is not such a good insulator. Fig. 98 is a long glass tube (2 ft. long) with an electrode (A and K) at each end, and a big potential difference is applied to A and K, A being the *anode* or positive electrode, and K the *cathode* or negative electrode. Our air-gap is

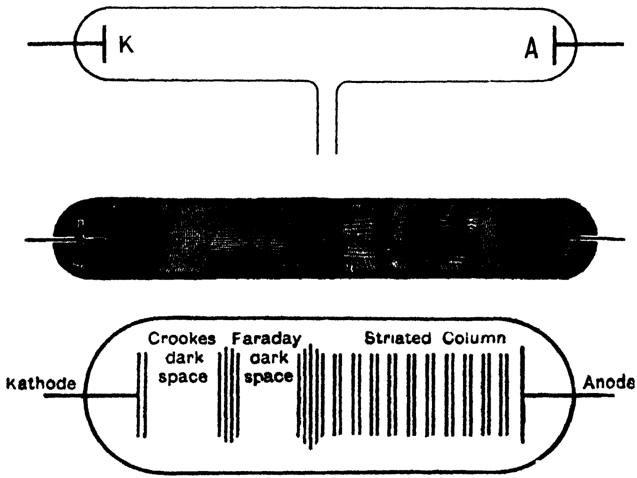


FIG. 98.

so long (2 ft.) that no spark—no electricity—passes. The side tube is joined to a pump, and the tube gradually exhausted, *i.e.* the gas pressure is gradually reduced. If the room be darkened, and the results as exhaustion proceeds be watched, we note the following:—

(1) The electrodes begin to glow and streamers begin to stretch from them.

(2) At gas pressures fairly low, say of the order 1 cm. of mercury (atmospheric pressure is 76 cm.), the " discharge "

is a luminous column stretching from a little distance from the cathode up to the anode. It is called the *positive column*, and its colour depends on the gas in the tube.

(3) At lower gas pressures the positive column breaks up into bright shells and dark patches; there is a dark space near the cathode (between it and the first bright shell) known as *Faraday's dark space.*

(4) Most of the glow on the cathode moves from it, and another dark space appears between this and the cathode, known as *Crookes' dark space.*

(5) At lower gas pressures the Crookes' dark space extends until it practically fills the tube, and the glass walls opposite the cathode glow, the colour depending on the kind of glass—with lead glass blue, soda glass yellowish-green. If the glass be coated with certain substances we get certain definite colours—with corundum, bright crimson, with zinc sulphide, bright blue.

It appeared quite clear to the early experimenters that " something " was coming from the cathode, and that this something when it bombarded the glass, etc., caused the latter to glow. Further experiments showed that this emanation from the cathode was shot out at right angles to the cathode surface wherever the anode happened to be, and that it heated bodies on which it fell. The name *cathode rays* was given to it. Other important facts were soon discovered, notably that it could be deflected by a magnet, or by an electrified body, and the deflection was the same as it would have been in the case of a stream of negatively charged particles.

Goldstein (1876) contended that this emanation from the cathode consisted of *waves* in the aether like light and wireless waves, a view long upheld in Germany, and the name which had been applied, viz. cathode rays, seemed appropriate. In England, Crookes (1876), Varley, and others contended that they were not waves but negatively charged *particles*, and this view was finally proved to be

correct. *Cathode rays are really electrons shot out from the cathode,* and it would be better to use some such name as cathode *stream* instead of cathode *rays.* The cathode rays were discovered by Plücker in 1859.

Incidentally, if the potential difference is sufficiently high and the gas pressure *very, very* low, so that the cathode rays have a *very big* velocity, then when they strike a solid body—particularly a dense substance like tungsten—*the body emits a radiation, a wave motion in the aether,* known as X-rays. X-rays have the same velocity as light and wireless waves, but they are much shorter in wave-length (higher frequency). Remember that cathode rays are *streams of electrons,* but X-rays are *waves in the aether.*

At still lower gas pressures than (5) the discharge decreases and at *exceedingly high vacuum* no current would pass.

In your studies so far you have had other illustrations of electrons coming from a cathode (negative electrode), which, therefore, are these same cathode rays. In a valve electrons are ejected from a heated filament cathode and pass through the space to the positive anode or plate. In the iconoscope electrons are also given off by a heated cathode, are pulled forward by a positive anode, and pass on towards the other end of the tube: and, moreover, in the iconoscope you move the electron stream about by electric or magnetic fields just as the early experimenters moved their cathode rays about and proved they were negative. The electron-image camera is another case where electrons are ejected from a cathode. And you have had other examples.

2. Using the Cathode-Ray Tube as a Television Receiver

THE TUBE AND HOW IT WORKS.—C.R. tubes in some form or other have been used in electrical laboratories for years, but Fig. 99 shows a typical one as used in television receivers. It is made of glass, is exhausted, and is of the order 18-26 in. in length and 6-14 in. in diameter at the large end, although bigger ones have been made. The

picture is built up on the large, circular, flat end of the tube. The important "working parts" are situated in the narrow part of the tube, so we will begin at the narrow end.

FIG 99.

A Cossor high vacuum cathode-ray tube for high definition television. This tube is $12\frac{1}{4}$ inches in diameter.

At the extreme narrow end we have a filament (cathode) K [Fig. 100 (*a*)], which is heated by passing a current through it just as is the filament of a valve. The filament is rather

thick, is oxidised, and the current sent through it is of the order of about an ampere: this current can be supplied by a battery, or from mains.

As in the case of the valve, the agitation due to the heat and the moving electrons of the current is so great that some electrons are ejected from the filament into the space outside it. These would tend to form a cloud near the filament, some returning to it, and in any case tending to obstruct the escape of other electrons from it. To prevent this and to get the ejected electrons to pass on with a high velocity into the wide part of the tube, a disc-anode, A_1, (pierced with a central hole) is fixed in front of the filament cathode, the anode being kept at a high positive potential relative to the cathode. This attracts the electrons, accelerates them towards it, and some pass on through the hole with a high velocity towards the other end of the tube. Note particularly that the anode is not there to seize hold of the electrons itself: it is there to pull them forward, to accelerate them, and make them pass on through the hole with a big velocity. In fact an anode like this is sometimes spoken of as an *accelerator*—a good name, for that is really what it does: sometimes it is spoken of as the "gun," but this is—scientifically—not a suitable name.

Now we not only want a stream of electrons moving with a big velocity right up to the large end of the tube, but we want it to be a *narrow* and *intense* stream: we want it to be of small cross-section, and we want it to contain as many electrons as possible. It is really going to do the "scanning" to build up the picture on the large end: it must therefore be intense and small where it hits, just as our scanning spot-light in previous methods had to be as strong and as small as was practically possible. Put another way, the stream must be *focused* on the large end of the tube, and it must be intense.

The anode hole certainly ensures a narrow stream to some extent, but as electrons repel each other they tend to spread out as they leave the filament-cathode, so that

some strike the anode instead of the hole and are wasted so far as the top end of the tube is concerned [Fig. 100(*a*)]. To prevent this spreading and wasting, and thus get as many electrons as possible to pass through the anode hole, a cylinder, S, is put round the cathode and given a suitable negative potential: it therefore repels the electrons and squeezes them, as it were, into a narrow beam along its axis, so that they shoot through the hole as a narrow intense beam to pass on at a big velocity. This cylinder is spoken of as the *negative cylinder* or the *Wehnelt cylinder* (after the inventor), or the *shield*. It must not be too negative, however, or it will repel the electrons back to the filament. [Fig. 100 (*b*).]

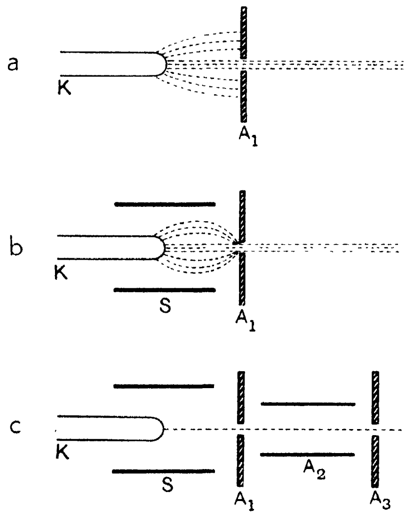


FIG. 100.

But further refinements were made in order to ensure a narrow intense beam of electrons focused on the large end of the tube—for bear in mind that the electrons in the beam still repel each other, and therefore tend to widen the beam after it has passed through the hole in the anode. After the first disc anode with its central hole there is a second anode, A_2, in the form of a tube, and then a third anode, A_3, in the form of a disc with a central hole. The anodes (or accelerators) are at positive potentials, the second being at a higher positive potential than the first, and the third at a higher potential than the second. [Fig. 100(*c*).]

To properly explain the "focusing" action on the electron stream of an arrangement of this sort it would be necessary to go rather fully into the science of Physics, so we will merely say this here:– It is well known that a beam of light is often brought to a focus at a point, say, on a screen, by using two or three lenses, and the focusing can be adjusted by varying the distances between the lenses. In the case of a beam of electrons we can bring them to a focus on a screen by means of electric fields due to plates at different potentials, and the focusing can be adjusted by varying the potentials of the different plates. If electrons, for example, suddenly pass from an electric field to another one of greater accelerating power they are acted on much in the same way as a beam of light is when

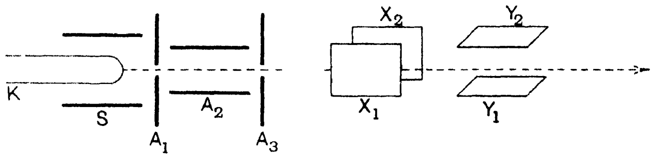


FIG. 101.

it passes through a convex lens. Our various positive anodes therefore act like a lens system, and focus the electron beam at the end of the tube. Incidentally it is the field between the second and third anodes in the present case which does the chief lens-action, and the potential of the second anode is what is usually varied to adjust the focusing.

As a general guide to the potential values, the third anode may have a voltage of the order 3000, the second 700-800 (this is the focusing control, and it has about $\frac{1}{4}$ of the third anode voltage), the first about 100 up to 700, and the shield may have a negative voltage up to about 50. In some cathode-ray tubes the first and second anodes are combined, *i.e.* there are only two anodes (three separate ones are preferable, for this ensures that focus-controlling

does not affect *brightness*): in one tube of this type the maker's rating is second anode voltage 800-2000, first anode voltage 250-800, and shield negative voltage 10-100.

We have said that the narrow, intense beam of electrons — the cathode rays—is going to scan the large flat end of the tube. It has therefore to do, say, 240 horizontal journeys across the end in a complete scan, or 6000 per second, with a rapid fly-back at the end of each journey, and it has at the same time to do 25 vertical journeys per second with a rapid fly-back at the end of each vertical journey. It has, in fact, to do those two saw-tooth motions simultaneously which were dealt with in Chapter V.

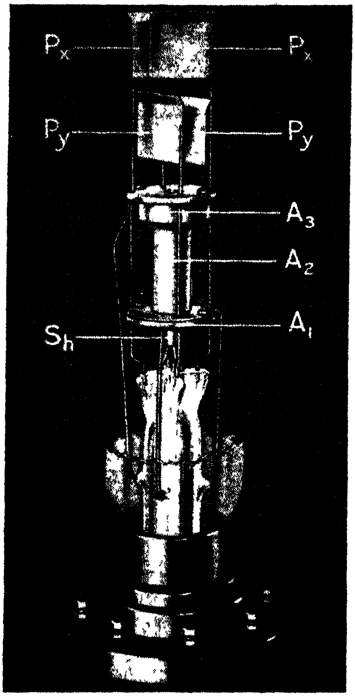


FIG. 102.

S_h = Shield, $A_1A_2A_3$ = Anodes, P_xP_y = Deflecting plates. There are 10 base-terminals, viz. cathode (2), shield (1), anodes (3), deflecting plates (4).

And the two saw-tooth motions are brought about in a way we have already mentioned. In the iconoscope and the electron-image camera the two motions were brought about by two pairs of deflecting-coils, each pair carrying the necessary saw-tooth varying current. In the cathode-ray tube two pairs of varying potential plates are used for the purpose. One pair of plates, Y_1 and Y_2, is fixed horizontally, and the other

pair, X_1 and X_2, is fixed vertically, the plates being inside the tube—not outside like the coils of the iconoscope and the electron-image camera. (Fig. 101.) The necessary saw-tooth varying potential is applied to X_1 and X_2 to bring about the saw-tooth horizontal movements of the electron stream over the end of the tube, and the necessary saw-tooth varying potential is applied to Y_1 and Y_2 to bring about the saw-tooth vertical movements at the same time. These two varying potentials are each produced by an arrangement called a *time-base* (or *time-base generator*), the two together being spoken of as the *double time-base*. We will explain how these time-bases work presently.

Note again, in passing, the difference between deflections brought about by plates (electric fields) and those brought about by coils (magnetic fields): the vertical plates X_1X_2, for example, which have a horizontal field, cause the horizontal movements. Compare with the effect of coils. (See pages 112, 120.)

Figs. 101 and 102 show the arrangement of these various parts inside the narrow portion of the tube.

The inside of the large, nearly flat end of the tube is coated with a fluorescent material, *i.e.* a material which fluoresces, or glows, or emits light, when it is hit by electrons. Calcium tungstate or zinc silicate in some form or other are generally used for this purpose. The result is therefore that we have a small patch of light at the point where the narrow electron stream (cathode rays) strikes the fluorescent material—the "screen," as it is called—and *the more intense the stream of electrons the brighter is the spot of light.* Further, if the electron stream moves horizontally across the screen it produces a patch of light at each point as it passes along, but as it is moving very rapidly (say $\frac{1}{6000}$ sec. to travel across) we do not see the separate spots but a continuous horizontal line of light. In the same way, if the stream moved vertically downwards in $\frac{1}{25}$ second we would see a continuous vertical line of

light on the screen. And, finally, if the stream performs its complete scanning action over the end of the tube we will see a complete area of light—the " picture area," as we called it in Chapter III. (due to persistence of vision).

It is clear, then, that if we can " modulate " this light appearing at the end of the tube by the varying signal output of the wireless receiver, *i.e.* by the picture signal, we will be able to build up on the picture area an image of the scene televised. You will remember that in the low definition disc receiver of Chapter III. the output of the wireless receiver was used to modulate the light of the neon lamp in order to produce the picture, whilst in the drum receiver the wireless receiver output was applied to the Kerr cell to modulate the light from the projector lamp passing through the prisms combination.

Now in the cathode-ray tube it is the electron stream which produces the light where it strikes the screen, and we have said that the more intense the stream—*i.e.* the more the electrons in it—the brighter is the light. Hence one plan at once suggests itself, viz. to use the output of the wireless receiver to vary or modulate the intensity of the electron stream, thus varying or modulating the light on the screen exactly in accordance with the light and shade of the object or scene televised. This is referred to as *intensity modulation*, and is mainly employed in practice.

Various methods have been suggested for carrying this out, for, of course, in varying the intensity of the stream we must not upset that focusing of the stream which results in a very small cross-section exactly at the screen where it strikes it. With the tubes of to-day, however, that focusing is well provided for by the multiple anode method we have explained. One method of modulating the intensity of the stream in order to build up the picture is to apply the varying output of the wireless receiver to the Wehnelt cylinder or shield (which already has a negative bias) surrounding the cathode. This varies the potential of the cylinder relative to the cathode, varies

the *intensity* of the stream of electrons passing through the anode holes, and varies the light on the screen accordingly; and it does this exactly in proportion to the output and therefore to the light and shade of the object televised. Thus the picture is built up.

The output of the receiver, *i.e.* the picture signal, is virtually applied between shield and cathode as roughly indicated in Fig. 103. This figure, of course, is only intended to convey the *idea*: the actual circuit is considerably modified in practice although the general idea is the same.

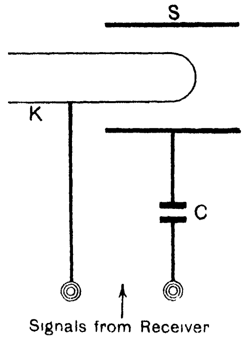


FIG 103.

We saw in previous pages that synchronising pulses—one at the end of each line and a distinct one at the end of each picture—were sent out from the transmitter in their proper position with the picture signal, and that these were separated out by suitable valve circuits in the wireless receiver. In the present case the synchronising

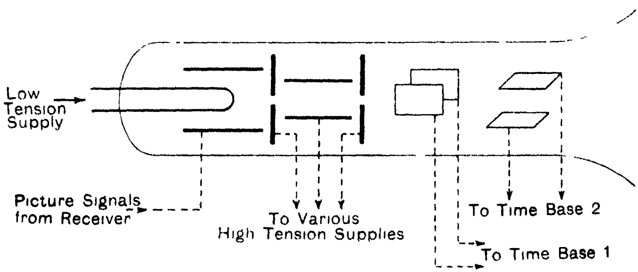


FIG. 104.

pulses are taken from the receiver, and passed to the time-bases which control the deflecting plates, *i.e.* the scanning: but we will come to this later.

Fig. 104 gives an outline sketch of the preceding facts.

A FEW ADDITIONAL POINTS ABOUT C.R. TUBES.—In wireless valves the inside of the glass often has a silvery appearance which is produced when the valve is made by a process known as "gettering." Similarly the inside of a cathode-ray tube right from near the electrodes to the edge of the screen is covered with a conducting coating. This coating is not of a silvery nature, however, for that would reflect light and interfere with the picture: it has a dark surface, and is really a graphite film, colloidal graphited water containing approximately 18 to 22 per cent. graphite by weight being used for the purpose. ("Aquadag" is its registered name.) It is a conductor (high resistance), and often acts as an additional anode playing its part in the focusing.

As the spot on the screen of the C.R. tube flies back at the end of each line and again at the end of each picture, the question naturally arises, does this mar the picture? The answer to this brings in another fact about electrons bombarding a fluorescent screen. If an electron stream moves gradually and *relatively slowly* along a screen, a line of light is produced, but if it moves *very, very quickly* little or nothing can be seen. So far as the horizontal fly-backs are concerned the movement is so quick that they cannot be seen. The fly-back between pictures takes a longer time, and may produce a slight defect, since it runs in a curved path more or less diagonally right across the picture-area from the end of the last line to the beginning of the first. To avoid any marring effect special devices are employed. It is possible to black the fly-back out by applying a suitable negative pulse to the cylinder of the C.R. tube during the picture fly-back period; or it is possible to make this fly-back path lie outside the picture area instead of diagonally across it. Remember that in using the word "slowly" we mean "in a *relative* sense": all the movements are "fast" as we ordinarily use the term.

The modulation system we have dealt with, viz applying the picture signal to the cylinder to vary the *intensity* of the electron beam, is called, as already stated, *intensity modulation* it depends on the fact that the light at any point on the screen depends on the number of electrons which bombard that point But as mentioned above, the

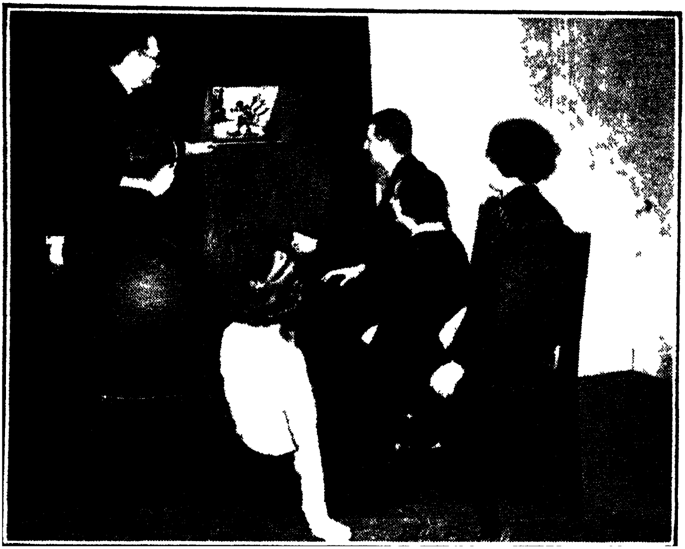


FIG 105 HOME RECEIVER FOR TELEVISION

This gives a black and white picture 12 inches × 9 inches, which is so bright that it can be distinctly seen even when room lights are "on" Another model gives pictures 10″ × 7½″ (Baird Television Co)

light at any point also depends on how long the electron beam stays there and keeps up its bombardment· we said above that if the beam moved relatively slowly it produced a bright light (if faster it produces less light), and if it moved exceedingly fast it produced practically none. We can thus get a varying light and shade along, say, a scanning line by varying the speed at which the beam moves along

different parts of it—quick for dark parts, slower for light parts.

This idea is the basis of a cathode ray television system developed in the laboratories of Messrs. Cossor by the experiments of O. S. Puckle and L. H. Bedford, and the modulation system is referred to as *velocity modulation*. The televised image, for example, is produced by varying the speed of the scanning spot so that it moves relatively slowly where bright parts are involved and quickly where dark parts are involved. The method has certain points in its favour. Bright parts are particularly good and detailed, but detail is not so good in dark parts: this can be remedied by a certain amount of intensity modulation in conjunction with the velocity modulation in these parts. As the Television Committee, however, has decided on intensity modulation (Baird and E.M.I.), and as velocity modulation at the receiver cannot be used with a transmitter using constant speed scanning, we need not go further into this highly interesting and clever system: we think more will be heard of it, however, in the future.

The general colour of the picture depends on the material used for the screen: tubes are available which produce pictures in blue, or green, or sepia, or practically black and white, sepia being quite a favourite colour with many makers. Various picture sizes are in use in home receivers: amongst these may be mentioned 6 in. × 4½ in.; 8 in. × 6 in.; about 10½ in. × 8 in.; 12 in. × 9 in. (Note our old friend 4 : 3 in these cases.) Large screen television will be referred to later.

The C.R. tube we have dealt with has been of the "hard" or high-vacuum type, for that is mainly used in television. There is, however, a "soft" type containing a gas—generally argon or helium—at low pressure. The internal construction is simpler than the high vacuum tube in the sense that the focusing arrangement is not so complex: there is often merely the cathode, the cylinder

shield, and a perforated disc-anode (and, of course, the usual deflecting plates). This simplified focusing equipment is due to the fact that the gas in the tube plays the main part in the focusing, and the tubes are often called *gas-focused tubes*. As the electrons travel along the tube from the cathode they collide with molecules of the gas, and they " hit " so violently that in some cases electrons are driven out of the gas atoms leaving the remaining part positively charged, *i.e.* leaving positive ions. Now these positive ions are heavy compared with electrons, and much more sluggish in their movements. They therefore loiter about in the beam's cross-section for a time, and as they are positive they attract the electrons in the beam, thus drawing them towards the centre and preventing them from spreading: in this way a narrow beam of electrons is maintained. In constructing the tube the makers so adjust the gas pressure that the beam is brought to a very narrow cross-section at the screen. The ideal tube for television, however, is the high-vacuum one previously described.

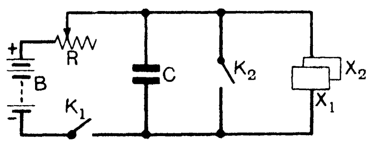


FIG. 106.

3. How the Time-Bases (or Time-Base Generators) Work

We have referred to two time-bases which control the scanning of the screen of the C.R. tube by giving the two necessary saw-tooth potential variations to the two pairs of deflecting plates—one time-base controlling the line frequency of, say, 6000 per second, the other the picture frequency of, say, 25 per second.

Now suppose we have a condenser C (Fig. 106) joined to a battery B through a variable resistance R. On closing the key K_1 the condenser becomes "charged," and the rate at which it is charged may be varied by altering R. For the present we will assume that it is gradually and uniformly

charged (which is not quite true—it charges faster at the beginning than towards the end), so that we will say the potential on the condenser (*i.e.* the *potential difference* between its plates) *uniformly increases.* Suppose now K_1 is opened, and the plates of the condenser joined by closing K_2: there is an immediate rush of electrons from the negative to the positive plate of the condenser discharging it (again not quite true), so that the potential on the condenser (*i.e. potential difference* between its plates) *suddenly drops.* Here we have a case then of a condenser gradually charging and suddenly discharging, the potential difference on it gradually increasing and then suddenly decreasing. And if anything were joined to the condenser —say one pair X_1X_2 of the deflecting plates in our C.R. tube—the potential difference on them would vary in the same way: the potential would gradually rise corresponding, say, to AB in Fig. 84, and then quickly drop corresponding to BC—the saw-tooth variation necessary to produce the saw-tooth movement of the spot on the screen. This is the fundamental principle of the action of a time-base.

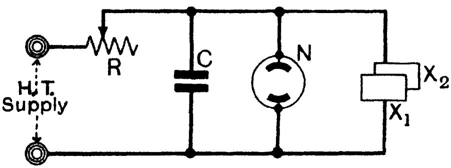


FIG. 107.

For one time-base we must so choose the condenser capacity, etc., that it is *steadily and uniformly* charged in about $\frac{1}{6000}$ second, then *quickly* discharged, thus producing the line movement of the light spot on the screen and the sudden fly-back. For the other time-base the condenser must be *steadily and uniformly* charged in about $\frac{1}{25}$ second, then *quickly* discharged, thus producing the downward movement of the light spot and the sudden fly-back at the end of the picture. And both must act together to get the lines "edge-to-edge." (For simplicity, "times" above neglect times for fly-backs and synchronising pulses.)

It is clear, however, that the above (Fig. 106) is not a practical method. There must be some device which will automatically discharge the condenser periodically at the *correct* instants, say, for example, *exactly* at the end of each scanning line, and the neon lamp was found to be suitable for the purpose. One of the points we noted about a neon in Chapter III. was that it did not pass a current until the pressure across its terminals reached a certain voltage, which we called the starting or striking voltage: when this voltage is reached, a relatively big current passes. Suppose, then, we modify our arrangement as shown in Fig. 107, where C is our condenser, R our variable resistance, N a neon lamp, and X_1 and X_2 one pair of deflecting plates

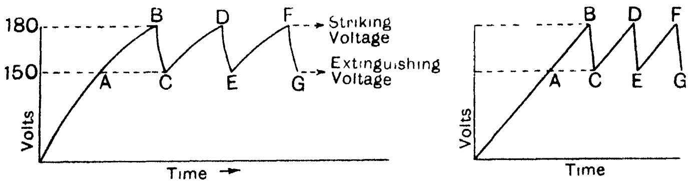


FIG. 108.

The curve on the left is the actual curve: matters would be better if it were like the curve on the right.

in our cathode-ray tube. The condenser is, say, gradually charged so that the potentials on the condenser, on the neon, and on the deflectors rise uniformly: this corresponds to our gradually rising potential line AB of Fig. 84, and produces a horizontal movement of the spot at constant velocity on the screen. When the potential difference on the condenser, etc., reaches the striking voltage of the neon, the latter passes current, and for an instant this current demand is so heavy that the condenser in providing it discharges very quickly. Of course, the voltage rapidly falls in step with this, and gets so low that it cannot keep up the neon's requirements, so that the latter is extinguished: the condenser now proceeds to recharge. The quick drop in voltage corresponds to our sudden dropping

potential line BC of Fig. 84, and produces the quick fly-back of the spot on the screen. The voltage at which the neon is extinguished is called the extinguishing voltage.

The preceding time-base is still primitive and has serious defects. The saw-tooth nature of it is shown in Fig. 108, which should be compared with the more ideal case of Fig. 84. The potential rises uniformly in Fig. 84 (*straight* line AB), but it does not in Fig, 108: the effect of this in the case, for example, of the time-base controlling the horizontal scanning would be to push the picture details towards the ends of the scanning lines on the screen where the spot is moving more slowly. Again the striking voltage and extinguishing voltage do not differ enough in value (30), *i.e.* the deflecting or "sweep voltage" is not large enough, and may not carry the spot the full length across the screen. Finally the saw-tooth variation only uses a small part of the total voltage available from the battery (look at the curve) so that it "wastes voltage."

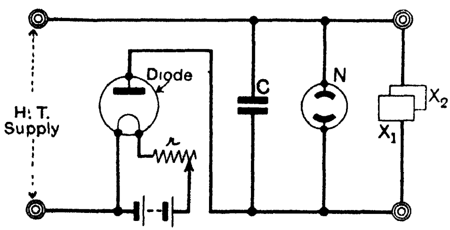


FIG. 109.

Improvements were therefore made whilst still making use of the same principle, viz. the gradual charge and rapid discharge. To get more of a straight line effect like Fig. 84 a diode valve (page 37) was used instead of the varying resistance R of Fig. 107, and Fig. 109 shows the circuit. The diode valve must be worked as a "saturated diode," as we call it, *i.e.* the filament current is made small (it can be regulated by the rheostat *r* in the filament circuit), in which case the current through the valve or the plate current is nearly steady and constant, and independent of

the voltage on the valve. We thus have a more or less steady uniform current flowing into the condenser, so that *the potential on the condenser, etc., rises approximately uniformly,* giving us that *straight* sloping line AB of Fig. 84, and a steady movement of the scanning spot along the screen. In other respects the action of this time-base is as already explained.

Matters are further improved, and a still more " linear " effect produced if a pentode valve (page 42) be used instead of the saturated diode. Moreover by varying the potential of the grid of the pentode we can alter the plate current and therefore adjust the rate at which the condenser is charged, and therefore alter the frequency of the time-base to fit the requirements. (Remember that a definite frequency is required for each time-base according to the line frequency and picture frequency used at the sending end.)

Yet a further improvement was made by substituting a gas-discharge relay, as it is called, for the neon lamp. This is a triode valve (page 38) in the sense that it has a filament and plate with a grid between them, but it is gas-filled (mercury vapour or neon). A property of this relay is that if the grid be made negative, and this negative be made very large, no discharge will pass through the relay between filament and plate, even if the voltage on the plate be high, but if the grid be much less negative a discharge passes, and goes on until the extinction voltage is reached (15-30 volts). The voltage at which a discharge commences can therefore be varied by varying the voltage on the grid of the relay. With the neon lamp the " sweep-voltage " was settled by the difference between the ordinary striking and extinguishing voltages, and might not be sufficient to make the spot sweep the full length across the screen: with the gas relay we can make the sweep-voltage just what we require by raising or lowering the voltage at which the discharge and potential drop begin (within the limits, of course, of the particular type of relay used).

Fig. 110 gives the circuit of a time-base employing a pentode and a gas discharge relay. The potentials on the grid of the pentode and on the grid of the relay are adjusted by what is known as the "potentiometer method," *i.e.* by varying the points of contact of K_1 and K_2 on the resistances shown. The two deflecting plates of the cathode-ray tube are joined to X_1 and X_2. The contact X_1 on the resistance shown can be varied: sometimes the scanned area on the screen is not quite central—it may, for example, be off to one side—and in this case X_1 is adjusted to shift the spot and centre the picture. Another time-base similarly arranged is used for the second pair of deflecting plates.

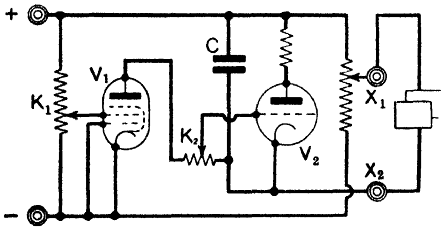


FIG. 110

V_1 = Pentode. V_2 = Gas discharge relay. The heaters of the cathodes of V_1 and V_2 are omitted for simplicity.

We saw that at the transmitting end, synchronising pulses were sent out in their proper position with the picture signal—one at the end of each line, another at the end of each picture—and that the pulses were filtered out by the receiver. The picture portion of the signal is, of course, applied to the cylinder of the C.R. tube. The synchronising pulses are passed from the receiver to the appropriate time-base, and applied to the grid of the gas-discharge relay: in the one time-base the pulse "times" the discharge and "end of line," and in the other the picture repetition.

The above gas-discharge relay method is the one usually employed to produce the quick discharge and rapid fly-back, but various other methods have been suggested,

and an outstanding one which has proved very successful is the subject of a patent by Messrs. Cossor. This consists of a high frequency pentode valve and a triode valve—hard (high vacuum) valves—such as are used in wireless: these take the place of our gas-discharge relay. The triode is really the discharging valve, and it acts in conjunction with the pentode as trigger. The grid of the triode is joined to the plate of the pentode, and the grid of the pentode to the plate of the triode (Fig. 111*a*). The plate circuit of the triode contains a resistance R, and it is therefore the potential changes on this—the voltage drops across it—which are applied to the grid of the pentode.

Now before considering the action just recall these two elementary facts:—

(*a*) A decrease in the potential or voltage of the grid of a valve causes a decrease in the plate current, and a rise in the grid potential causes an increase in the plate current (pages 37-42).

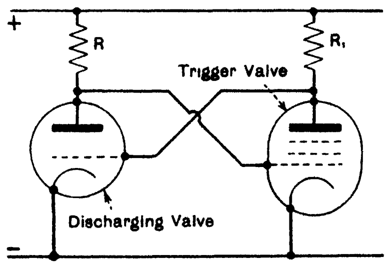


FIG. 111*a*. Principle of the discharging circuit.

(*b*) When a current flows through a resistance there is a "voltage drop" in the resistance, *i.e.* one end is at a higher potential than the other: this voltage drop is measured by multiplying the current (amperes) by the resistance (ohms) so that if the current increases the *drop* in volts is greater, and if the current decreases the drop in volts is less.

To proceed—suppose the condenser charged and that the triode (the grid of which has up till now been biased back—negative) begins to pass current. This means a *voltage drop in R*, and a decrease therefore in the voltage of the grid of the pentode which is joined to it. This decrease in the

voltage of the grid of the pentode means a decrease in the plate current of this valve and a *less voltage drop in* R_1 and as this is joined to the grid of the triode *this grid rises in potential or becomes more positive so that the plate current of the triode increases,* i.e. *the triode takes more current from the condenser.* Now this increased plate current of the triode results again in the lowering of the voltage of the grid of the pentode, which in turn, as already explained, results again in a rise in potential of the grid of the triode,

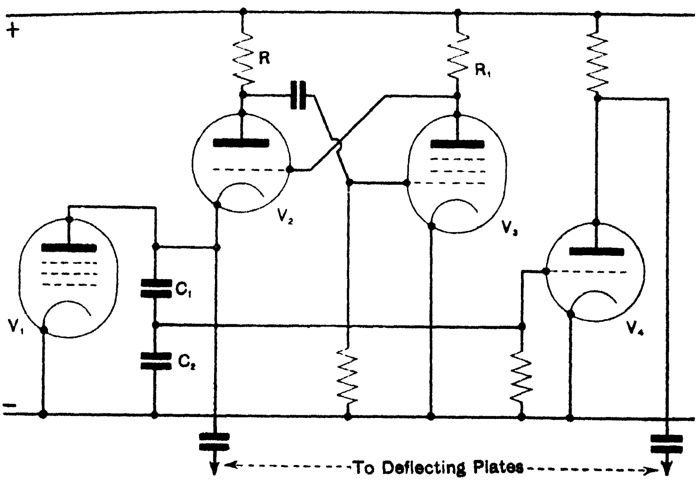
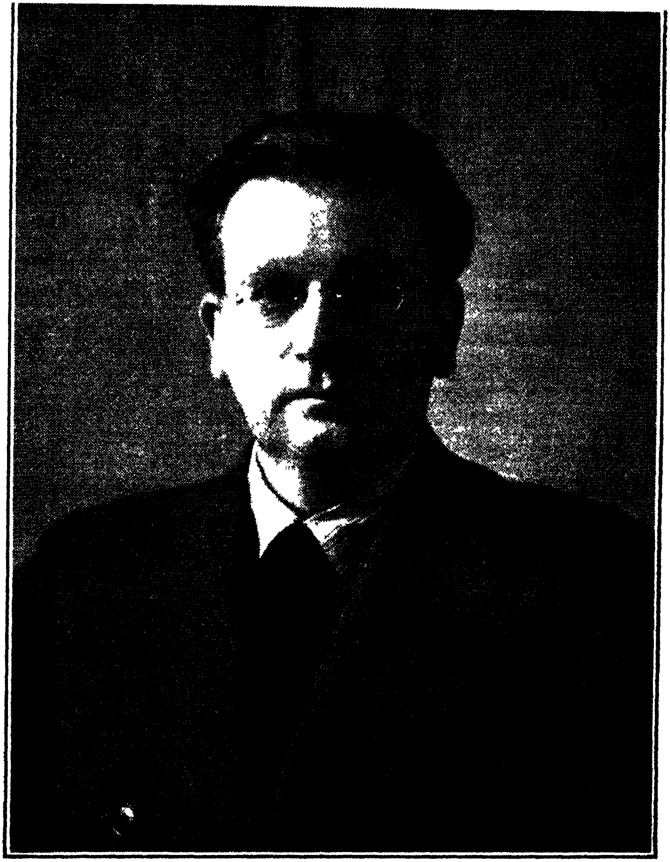


FIG. 111*b*. Part of the time-base circuit.

a greater triode plate current, and therefore more from the condenser, and so on. All these actions are extremely rapid, so that the first slight trickle of discharge is rapidly followed by the complete discharge of the condenser—and the quick fly-back.

The actual time-base of Messrs. Cossor works on this principle, but contains several modifications and refinements. A part of their circuit for one time-base is indicated in Fig. 111*b*. Here V_1 is the charging valve—the pentode



John L. Baird.

Pioneer worker and inventor in Television. Born Helensburgh, Scotland, 1888 Educated at Larchfield Academy, Royal Technical College, Glasgow, and the University, Glasgow.

of Fig. 110—and the "charging condenser" is the condenser C_1 with C_2 in series. V_2 is the discharging triode used with V_3 the "triggering" pentode which, as explained above, speeds up the discharge. R and R_1 are the plate circuit resistances of these two valves. A further valve V_4 is added to the circuit for increased efficiency and a balanced deflection: it is joined to C_1 and C_2 as shown, and the values are such that the plates of V_1 and V_4 undergo equal voltage swings (saw-tooth) but opposite in "phase," and these are applied to the deflecting plates of the tube. Further technical details of this time-base (or time-base generator) demand a sound knowledge of wireless theory, so we must leave it at that: but the general idea should be quite clear.

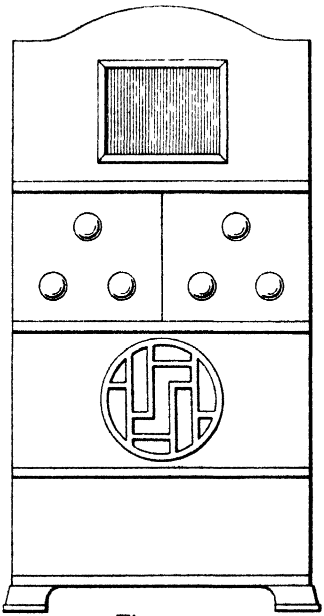


Fig. 112.

4. A High Definition Television Receiver

Figs. 105 and 113 indicate the general appearance of two of the modern H.D. television receivers, but before referring to them there is just one point which should be noted.

We have mentioned that in ultra-short wave working, sound and vision can be sent out on two wave-lengths which differ very little from each other, and yet there will be sufficient "spacing" to allow of that necessary 1000 kilocycles frequency sideband for the vision. Thus if the vision was sent out on a 6-metre carrier (frequency = 300,000 ÷ 6 = 50,000 kilocycles) and the sound on 6·3

metres (frequency = 47,619 kilocycles), the frequency space between them would be over 2300 kilocycles although the difference in wave-length is only ·3 metre. *It is quite common practice, therefore, for the one receiver to receive both sound and vision on the one aerial.* The aerial tuning system is made sufficiently flat to embrace both transmissions. Then an electrical device comes into operation the result of which is to practically separate the two signals. After this the signals pass to what really amounts to two separate wireless receivers, the sound signals going through one set (of more or less ordinary construction) to the loud speaker, and the vision signals going through the other set (of special construction to cope with wide frequency bands) to the cathode-ray tube, the synchronising pulses being filtered out to go to the time-bases. But all is contained in the one "receiver," and only one aerial is used. For the benefit of the technically-minded reader this will be referred to again later.

A usual method with receivers is to arrange the various sections on shelves in a cabinet one above the other, somewhat as indicated in Fig. 112. Thus the bottom compartment may contain the apparatus for converting the A.C. mains supply to D.C., and for supplying the electrodes of the tube with the requisite potentials (referred to as the *power pack and exciter*): the time-bases with their supply accessories may also be in this compartment. The next compartment may house the loud-speaker. The next shelf may carry the two receivers—sound and vision—the controls coming out on the front panel. The C.R. tube will be lying horizontally in the top compartment, an opening being made in the cabinet for viewing purposes. Numerous modifications of this general scheme are, of course, possible.

Fig. 105, page 147, is a receiver for both sound and vision, manufactured by Baird Television Ltd. This uses a large tube, so that for convenience it is fixed vertically, the large screen end being at the top and the narrow end at

the bottom of the cabinet. The picture is a very pleasing bluish-black and pure white, and its size is 12 in. × 9 in.: it is brilliant, and can be seen quite well in a normally illuminated room. If the room lighting is turned off matters are, of course, even better—in fact the picture area is so bright that it causes a well-defined shadow to be thrown on the wall behind of those looking into the receiver. To enable the picture to be seen by spectators sitting in front, the lid of the cabinet contains a mirror: this lid, when the receiver is in use, is fixed upwards at an angle of 45°, so that the horizontal image on the screen of the tube is reflected, giving an upright image in the mirror. For details of the controls and of the manipulation of the "knobs" on the receiver see page 202.

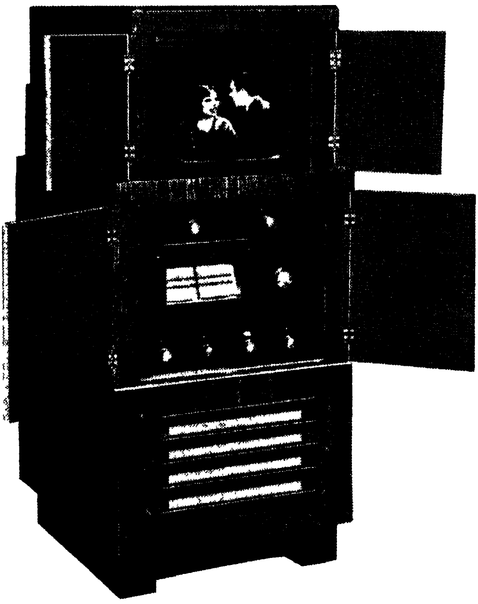


FIG. 113. THE COSSOR RECEIVER.
Picture 10 inches × 7½ inches.
Black and white.

Fig. 113 shows an excellent multi-purpose receiver made by A. C. Cossor Ltd. By the mere turning of a switch the set can be used for the reception of (*a*) the vision and accompanying sound from the B.B.C. television station;

(*b*) the sound alone (or any sound programme which may at any future time be sent out on the ultra-short wavelength used for the sound, viz. 7·2 metres); (*c*) the usual broadcasts on long and medium waves; and (*d*) gramophone records: in one model this latter reception is from a separate gramophone using a "pick-up," and in another model the gramophone, with record changer, is included in the set.

The picture is a pure black and white, 10 in. × 7¾ in., and is viewed directly on the end of the tube, the latter being arranged horizontally in the top portion of the cabinet. The sound and vision receivers are next in order, whilst the loud speaker and power packs, etc., are in the bottom of the cabinet. The operating knobs are seen on the central panel (Fig. 113). From the number of knobs and controls on television receivers some people have the impression that they will be difficult to manipulate, but this is not so: a television receiver is no more difficult to handle than an ordinary wireless receiver (see page 202).

Taking the controls of Fig. 113, their functions are briefly as follows, the set being used for television (vision and accompanying sound):—(*a*) The top left-hand knob is the *focus* control which, if correctly set, gives a sharply-defined picture on the end of the tube, and if incorrectly set, a blurred one: this control is, however, "pre-set" and need not be touched unless it has been accidentally moved. (*b*) The top right-hand is the *brilliance* knob which increases and decreases the brightness of the picture as a whole: this is usually set correctly when the set is installed, and further adjustment at any time to suit individual requirements need only be slight. (*c*) The bottom left-hand knob is the *tuning control* for television (vision and sound): with it the sound is "tuned in" to a maximum, and this automatically "tunes-in" the vision also; once set to the correct position it needs little or no further adjustment. (*d*) The next knob is the *contrast*: if incorrectly set the picture may be thin, or it may be

harsh, there may be too much contrast so that half tones are defective, and so on: this again, once correctly set when the instrument is installed, requires very little further adjustment. (*e*) The next in order is the *selector* switch: this merely puts the set to receive television or ordinary broadcasting or gramophone, etc. (*f*) The bottom right-hand knob is the *volume control* for sound whether the set is being used for television or ordinary broadcasting, etc. (*g*) Finally, in the centre of the panel is the station dial and knob for *tuning* when the set is being used for ordinary broadcast reception, *i.e.* as an ordinary wireless receiver.

In addition to the above controls on the front of the receiver there are others which are located at the back of it, but these are all *pre-set* when the receiver is constructed and installed, and do not require the attention of the looker-in at all. It will be clear from preceding pages that there are certain factors to be adjusted "once for all" in connexion with the time-bases, etc.: hence it is that behind the set are found controls for the horizontal sweep (picture width), vertical sweep (picture height), horizontal and vertical "shifts," synchronising, etc. But, as stated, all these are pre-set and normally do not need any attention on the part of the general user.

The preceding are typical modern receivers: there are, of course, several other models on the market by various manufacturers. In some the C.R. tube is horizontal and the picture is viewed directly on the end of it: in others the tube is vertical and the picture is viewed in a mirror inclined at 45°. Further, some models are designed for television only: others receive, in addition, the ordinary broadcasting on short, medium, and long waves.

5. Receiving Aerials for Ultra-Short Waves

As already indicated, it is necessary that aerials for ultra-short wave reception should be erected as high as possible (see page 96), and the position should be so

chosen that interference is reduced to a minimum. On these wave-lengths there is little interference from atmospherics: the greatest interference in home reception will probably be due to passing motor cars. Such interference rarely extends to a greater distance than 40 or 50 yards:

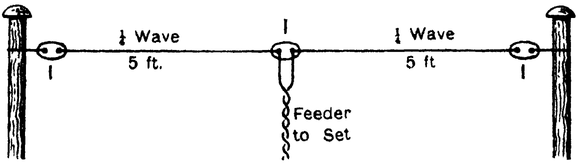


FIG. 114.

hence even in houses situated on a road where motor traffic is heavy, a high aerial placed at the far end of the garden at the rear of the house, and joined by feeder wires to the receiver, will meet all requirements in this respect.

The best type of aerial for the purpose is that referred to on page 96, viz. the *half-wave dipole*. Assuming a transmitting wave-length of, say, 6 metres (19½ ft.), this means a total aerial length of, say, 10 ft. The dipole aerial is in two halves, in line, end to end, the ends being 2-3 inches apart, so that each arm (Fig. 114) will be one quarter of a wave-length, *i.e.* 5 ft. If the aerial be supported horizontally at its extreme ends from, say, two poles or buildings, the arrangement will be as in Fig. 114, where I, I, I are insulators. A "feeder" from the two inner ends to the receiver in the house may consist of twisted flex (rubber covered), and it is advisable (not essential) to arrange that the feeder length is some odd number of quarter wave-lengths, *i.e.* 3, or 5, or 7, or 9, . . . times 5 feet. With this point in mind the lead-ins or feeder may be as long as is necessary in order to have the

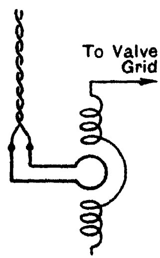


FIG. 115.

aerial-proper in the best position. At the house end of the feeder we have the *two ends* of the flex to couple up to the receiver (instead of the single down lead we are accustomed to in ordinary wireless reception): the most satisfactory way is to join the two ends to a single or double turn coil which is "coupled" to the first grid coil of the receiver (*i.e.* it is wound on the same former and close to the grid coil, as indicated in Fig. 115): but this will be arranged for in the receiver. Instead of a twisted flex feeder two separate wires may be used, keeping them parallel throughout their entire lengths and 2-3 inches apart by suitable spreaders.

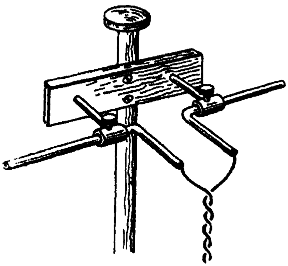


FIG. 116.

Fig. 116 shows another method. Here the two parts of the aerial are of copper rod or tube of about $\frac{1}{4}$ inch diameter and lengths of 5 feet of this are self-supporting. The gap between the two is at least 2 inches.

A modification of the above is the vertical dipole shown in Fig. 117, and this is the most suitable form to use for the reception of the Alexandra Palace transmissions (vertical dipoles are used at the Palace for the transmitting aerial). Several of these are on the market, some fitted with "reflectors" to improve reception (see later).

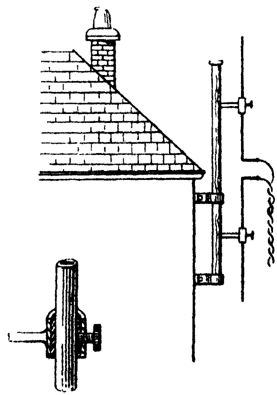


FIG. 117.

A better but more elaborate and expensive feeder arrangement is indicated in Fig. 118. Here the two wires leading to the receiver are kept apart throughout their entire length, but at regular distances

they are crossed over: this eliminates interference effects. *Eddystone cross-feeder blocks* are convenient for this purpose, for they can be readily inserted between the wires.

Another type of aerial for ultra-short wave work and television, and which is recommended for dual reception, has appeared in America, and is called the *double-dipole.* It consists of two dipoles for somewhat different wave-lengths. These are crossed at an angle to each other. One feeder line is joined to the right-hand half of one dipole and to the left-hand half of the other, the second feeder being joined to the remaining two halves. It gives better reception over a range of wave-lengths than the simple dipole, and is better adapted for reception of two wave-lengths—say sound and vision.

The simple half-wave dipole previously described is, however, quite satisfactory.

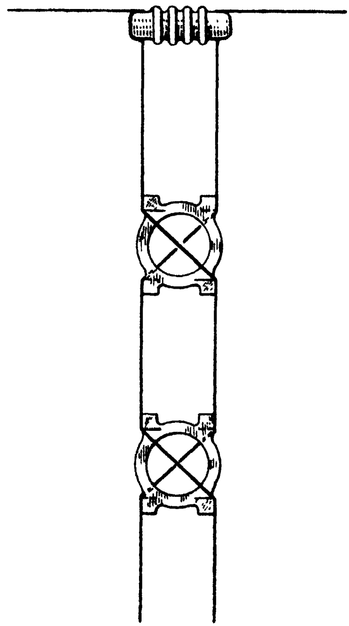


FIG. 118.

6. An Additional Point for the Technically - Minded Reader

There is one further point which may have roused the interest of the technically-minded reader, viz. how the wireless receiver is arranged so that sound and vision on different wave-lengths can be received at the same time with one aerial and one receiver (dual reception).

A proper explanation of the arrangement is really of a scientific and technical nature, and beyond the scope of

this book. We can therefore merely " hint " at the general idea for the benefit of those acquainted with " Wireless," and beginners may omit the section at present.

DUAL RECEPTION.—The receiving of two or more transmissions on different wave-lengths *via* one aerial and reproducing them simultaneously on two or more loud speakers or on a loud speaker and a viewer, really implies fresh ideas in the science and technique of wireless. But readers with a knowledge of wireless circuits and of the

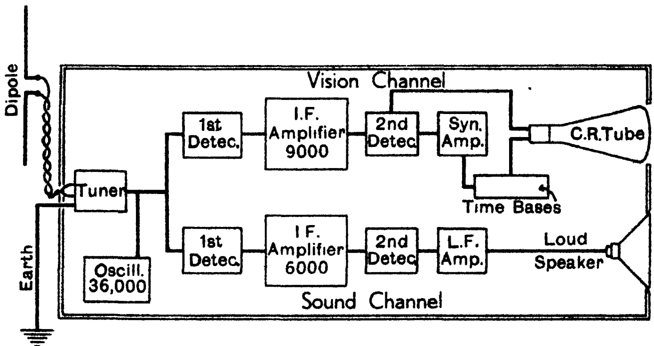


FIG 119

ordinary superheterodyne will readily see one method of doing it from the above diagram and figures.

Suppose vision is sent out on 6·6 metres and sound on 7·1, so that the frequencies are 45,000 kilocycles and 42,000 kilocycles approximately. Now suppose a local oscillator in the receiver is tuned to a frequency of 36,000 kilocycles: the *beats* it will produce with the above will evidently be of frequencies (45,000 – 36,000), *i.e.* 9000 kilocycles for the vision and 6000 kilocycles for the sound. Next the circuit (Fig. 119) divides as indicated into sound and vision channels, and it is in the intermediate-frequency amplifiers that the distinction between the 6000 and 9000 channels (sound and vision channels) is important, for whilst the sound amplifier

is more or less usual, the vision amplifier must have big amplification without sharp tuning. Note that the tuning system (resistance, inductance, and capacity) must be flat enough to accept both transmissions, and that it is the joint action of tuner and oscillator that converts the input into two signals which are virtually dealt with by two receivers—the sound receiver and the vision receiver.

The Alexandra Palace H.D. television wave-lengths are fixed at 6·6 metres for vision and 7·2 metres for sound: the "frequency space" between these two is practically 3800 kilocycles although the wave-lengths only differ by ·6 metre.

CHAPTER VII

TELEVISION IN THE CINEMA. TELEVISION IN COLOURS. TELEVISION IN THE DARK. OTHER TELEVISION SYSTEMS. TELE-PHOTOGRAPHY

IN the preceding chapter we dealt essentially with television reception in the home. We come now to large screen television which ultimately aims at the reproduction of an event at several theatres (and on the usual cinema screens) practically simultaneously with the happening of the event miles away; or the reproduction in several theatres of a film televised from a central studio. There are real difficulties associated with it, the chief of which is the large amount of light required for the screens which may be of the order 14 to 22 feet or more in width. However, progress has been made, and large screen work is being done: time and research will, no doubt, bring about such results as the public will require, viz. the same high standard as the present cinema.

1. Cinema Television

Baird's first "large" screen demonstration was on the stage of the London Coliseum in July 1930. In June 1931 a further demonstration with improved methods took place at the British Association, the picture in this case being 6 feet $\times$ 3 feet. Again in June 1932 Baird televised the parade and finish of the Derby which was received on the screen of the Metropole Theatre, the picture being 7 feet high and 9 feet wide. In September 1933 the Marconi Co. demonstrated at the British Association, their picture being about 6 feet square. We need not describe these earlier methods.

Perhaps the most successful method at the present time for the reception of high definition television on the large theatre-screen is a slight modification of the intermediate film method described in Chapter V. It is in use by the Fernseh A.G., Berlin (180 lines, 25 pictures per second), and the screen picture is about 13 feet × 10 feet (note again 4 : 3 ratio). A receiver at the theatre takes in the signals as usual, and the picture signals are passed to a Kerr cell to modulate the light from a projector lamp passing through a prisms arrangement—again, much as usual. The emergent modulated light is then focused (in the Fernseh method) on a scanning disc with 90 holes in a

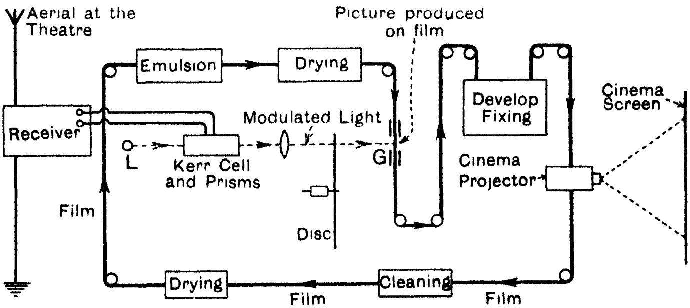


FIG. 120.

circle and revolving 50 times per second. The varying light coming through the holes is focused on an undeveloped film which is moving vertically through a gate, G: thus a picture is produced on the film line by line as the disc rotates. The film then passes through the various tanks (Chapter V.). *On leaving these it passes to the cinema projector* which projects the pictures on the cinema screen.

For economy in film the Fernseh A.G. use the " continuous loop " method at the theatre (Chapter V.): after leaving the projector the film passes through further tanks for cleaning, re-emulsioning, etc., and finally reaches the gate to receive further pictures. Again, for this work Fernseh

A.G. also use the intermediate-film method at the sending end so that, at that end, the televised films are negatives (again see Chapter V.). No "correction," however, is made for this at the sending end, for there is a "reversal" at the theatre when the picture is produced on the film: the picture projected on the screen is therefore positive. The whole business of developing, washing, fixing, and drying takes under 2 minutes. The necessary delay of the sound reproduction so that corresponding picture and sound come together is easily arranged. Fig. 120 gives a skeleton idea of the arrangement.

Modifications of this intermediate-film method at the theatre are, of course, possible. Baird is perfecting a system in which a cathode-ray tube picks up the signals from the receiver, and its pictures are photographed on the moving sensitive film by a special type of camera, after which the film passes to the tanks, the projector, etc., and is finally stored.

Yet a further line of investigation is being worked out by Baird. This uses a special cathode-ray tube which gives such brilliant pictures that they can be directly projected on a screen by a system of lenses. At present the screen pictures are only about 4 feet × 3 feet.

Finally, another Baird method is being developed—a mechanical method—in which a disc and drum are used together: the pictures are about 8 feet × 6 feet.

2. Television in Colours

Several methods have been proposed and demonstrated for this: the principles involved may be briefly indicated as follows:—

(*a*) As is well known to students of *Light*, Maxwell showed that there were *three primary light colours—i.e.* colours which could not be imitated by mixing other colours—viz. red, green, and violet, and that any other colour could be formed by mixing suitable proportions of these.

(We are not referring to mixing *paints* for picture painting, or to colour-printing on paper—these are slightly different stories.) Again, Young and Helmholtz showed that we have three sets of nerves by which colours are appreciated, the three colours to which the three sets respond being a particular *red*, *green*, and *blue*: they are thus not quite the same as the three primary light colours mentioned above. Red, green, and blue are therefore *three fundamental colour sensations*, and of course the actual " colour " we say a body is depends on the proportion in which the three sets of nerves are excited by it.

Further, remember that a piece of red glass only transmits red light, green glass only transmits green, blue glass transmits only blue. Similarly a red surface reflects only red, and so on.

(*b*) Now suppose for simplicity we are using disc scanning at the sending end, and that in front of the arc we put three " colour filters," as we call them, say red, green, and blue glasses, so arranged that during the first scan the red glass (which only transmits red light) is in front of the arc, during the second scan the green glass is there, and during the third scan the blue glass is in position. An automatic device can be arranged to keep up the regular movement of the filters into, and out of, position as required. Thus the object would be scanned in succession with red, green, and blue lights. Moreover, during the red scan only the red parts of the object (and parts containing some shade of red) would reflect the light to the photo-electric cells, and a similar remark applies to the green and blue scans.

At the receiver three filters—red, green, blue—would be so arranged in front of the lamp that they automatically change position in step with the change at the transmitter. Thus when the red scan is taking place at the transmitter the red filter would be in position at the receiver, thus giving in the picture the red parts which are reflecting red light from the object scanned: similar remarks apply to

the other filters. Owing to persistence of vision, however, the eye would not see separate coloured pictures: it would combine the impressions and see a complete picture containing all the colours in their proper positions and proportions. As it takes three scans to complete a coloured picture, the speed of the moving scanners must be increased: think about this and its effects.

A modification of the above might be adopted. The first line might be scanned with the three colours red, green, blue in succession, then the second line with the three colours, and so on.

(*c*) Recently cinema pictures in colours have become a marked success, the underlying principle being practically a *two-colour one*, viz. yellowish-red and greenish-blue, for experiment shows that combinations of these produce *a near approach* to various actual colours: the form of cinematography known as the "kinemacolor" uses the method. When the film photographs are taken, a disc with alternate yellowish-red and greenish-blue glasses rotates in front of the camera lens. At the theatre a similar disc is used in front of the projector lens, the timing being such that the reddish glass is in front when the picture taken through the reddish glass is being thrown on the screen: a similar remark applies to the bluish glass. These pictures run through the projector so quickly that the eye combines the impressions, and the picture is seen more or less in its natural colours. The "technicolour" film is on this principle: it is two films cemented together, one having been photographed through a yellowish-red screen, and the other through greenish-blue.

(*d*) The above has been applied experimentally to television, using a slight modification of the method previously indicated. At the sending end are two photo-electric cells, one with yellowish-red, the other with greenish-blue glass in front: these can be automatically put in and out of circuit so as to be employed alternately. At

the receiver are two lamps with similar filters: these can be put automatically in and out of circuit, the " reddish " being in circuit when " reddish " parts of the object are active at the transmitter, and so on. Again, by persistence of vision the impressions are combined, and a complete coloured picture seen.

So far, in this question of colour television, you will note that the experiments have involved mechanical scanners. Whether colour television reception on the cathode-ray tube can be made to become a success remains to be seen. The "colour" in C.R. tube reception depends on the screen material: it does not seem impossible to devise some arrangement whereby suitable salts might be placed in strips across the screen in such a way that " persistence of vision " would lead to the impression of a picture in natural colours. Research will decide this in due course.

3. Televising an Object which is in Total Darkness

Baird has conducted experiments whereby it is possible to " see " a person or object at a distance even if they are in total darkness (it is referred to as *noctovision*). For this he used infra-red rays, *i.e.* the dark heat waves (which do not produce " vision ") a little longer than the red (page 22). Instead of the usual spot-light an infra-red (dark) spot was used to scan the object televised, the object being, of course, in total darkness. The image was obtained, say on a screen, just as with usual methods.

Since infra-red rays can penetrate fog, the application of the above idea to detecting the presence of objects at sea in a dense fog is apparent. Imagine two ships approaching in a fog. The lights on A, for example, cannot be seen by B. The infra-red rays (dark) from A's lights, however (which do penetrate the fog), are focused by B on a scanning disc behind which is a photo-electric cell (a cell is used which is particularly sensitive to infra-red waves), and the resulting current is amplified and passed to a neon lamp

(also scanned by the disc) which, in consequence, glows. The glowing neon therefore indicates that there is a light ahead, and the presence of the on-coming ship, and its bearing, are detected. This apparatus was named by Baird the *noctovisor*.

Incidentally, a similar idea—infra-red radiation—is used in one method of *visible telephony* by which two people, carrying on a telephone conversation, not only hear each other but also see each other.

Amongst "odds and ends" of television may be mentioned the application of the picture signal to the construction of a "picture record" on a disc for use when required just as in the case of sound records. This was done by Baird a few years ago, and it is referred to as *phonovision*.

4. A Glance at a Few Other Television Systems and Suggestions

The television systems described in preceding chapters have all proved successful in practice. Many other devices have been proposed and experimented on from time to time, some of them to be subsequently abandoned. There are, however, a few which have made undoubted progress, and are undergoing satisfactory and even rapid development; but in many cases the firms have not yet made known the details. In this book we can only glance at one or two of the *general principles* involved.

(1) ONE DIMENSION SCANNING.—You have, no doubt, looked at a cylindrical mirror, and seen your face squeezed into a long and narrow vertical image, or if the mirror is at right angles to the previous position, you have seen your face stretched out horizontally and compressed vertically.

Now look at Fig. 121. Here we have a picture which we have marked off into a number of horizontal strips. By means of a device known as an "echelon prism" these strips can be pulled out as shown on the right of the figure.

If now a spot-light travels along as indicated by the space between the dotted lines, it will have very nearly scanned the whole picture in that one line movement. Clearly, the more the strips into which the picture is divided by the prism, the more nearly will the right-hand side of Fig. 121 become a straight line, and our scanning spot will therefore be able to take in the details of the entire picture in its one-dimension or line movement. A perfect system of this sort would evidently greatly simplify scanning operations which, at present, are both horizontal and vertical. Of course, at the receiving end another echelon device would be used to turn the line image back to its " area " formation.

(2) THE SCOPHONY SYSTEM.—This ingenious system of television seems to have a promising future, but to

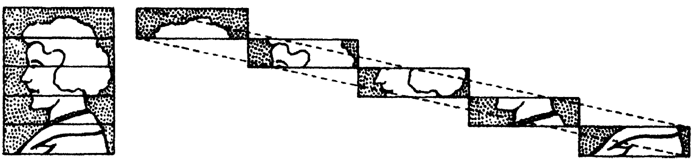


FIG. 121.

understand its action a clear grasp of the optics of cylindrical mirrors and lenses is necessary. In a way it may be said to involve two principles, the " germs " only of which are referred to above: the receiving system, for example, makes use of *two cylindrical lenses arranged with their axes at right angles, and between them a rotating echelon*, the modulated light source being at one side of the arrangement, and the screen at the other side. One cylindrical lens " focuses " a horizontal dimension, and the other, at right angles to it, focuses a vertical dimension. The echelon consists of a number of horizontal slices or laminations which are displaced relatively to each other in a kind of step formation, and each stepped surface handles a particular strip of the picture, only one slice passing light

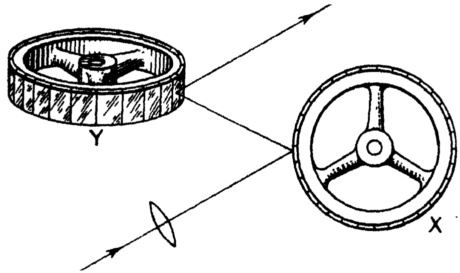


FIG. 122.

at any one instant. As indicated, however, an explanation of the complete working would necessitate a lengthy incursion into *optics*, and is beyond the scope of this book, so we must leave it at that. The system is due to G. W. Walton of the Scophony Co.

(3) MECHANICAL SCANNERS USING TWO MOVING SYSTEMS.—We have referred to the better and larger pictures with drums than with discs in L.D. television. When we consider drums for H.D. work, however, we see at once that the large mass, the big speed, and the large number of mirrors with the very small tilt between adjacent mirrors combine to render their employment almost impossible—unless some decided modification be made. The use of two moving members has been suggested (and used in some experiments) to minimise the difficulties. Thus for 240-line

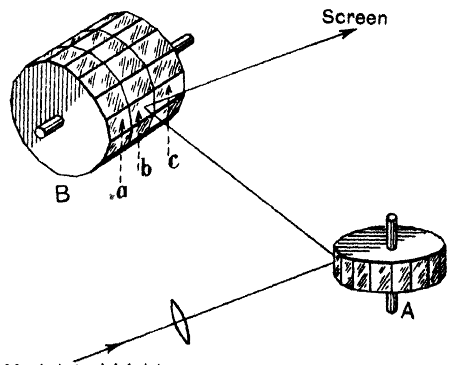


FIG. 123.

scanning at 25 pictures per second two drums X and Y (Fig. 122) fitted with mirrors and rotating about axes at right angles to each other might be used (mirrors parallel to their axes). X could have 120 mirrors rotating 50 times per second, and Y could have 25 mirrors rotating once per second. But the idea has many drawbacks.

Baird has patented a somewhat similar device (Fig. 123). A has 30 mirrors, and rotates at 50 revolutions per second. B has three sets of 19 mirrors, the three mirrors (*e.g.* *a*, *b*, and *c*) in each row being tilted at different angles, so that each produces a separate line on the screen, the lines being "edge to edge." The speed of B is such that while A makes a complete revolution, B changes from one horizontal row of mirrors to the next one. The number of scanning lines is therefore trebled.

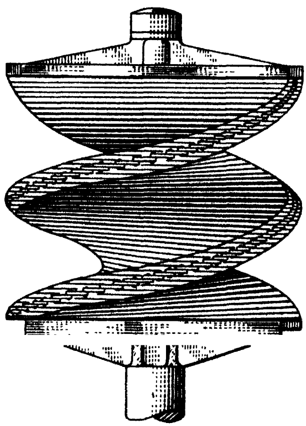


FIG. 124.

(4) MIRROR-SCREW SYSTEMS.—At the TeKaDe Television Laboratories in Germany the "mirror-screw" system has been brought to a fair standard of success: in its latest forms it is adapted to 180, 240 (and more) line scanning.

The mirror-screw is made up of a number of flat plates arranged one above another, each being twisted through an angle relative to its neighbour so that the whole pile forms a spiral after the style of a spiral staircase (Fig. 124). The edges of the plates form the mirror surfaces. The screw is rotated by a motor, and the picture is built up by the rotating screw: the picture is therefore seen by looking *direct* towards the screw. The number of flat plates used

gives the number of scanning lines, the length of the plates governs the length of the lines, and the thickness of a plate determines the width of a scanning line. It will be clear that when this screw rotates rapidly, anyone looking towards it will see, as it were, a single mirror surface.

Suitably placed in front of the screw so that its light falls on, or is reflected to, the screw, is a long source of light parallel to the axis about which the screw rotates. In L.D. reception this generally consisted of a mercury-vapour lamp of the narrow tube type. For H.D. with bigger screws the necessary very long tube-light presents a difficulty: it is therefore usual to employ a shorter light, and to use with it cylindrical lenses which stretch out the light as required. It is evident, then, that if this light be "modulated" by the receiver output, the rotating screw will reflect the modulated light in such a way as to build up a picture.

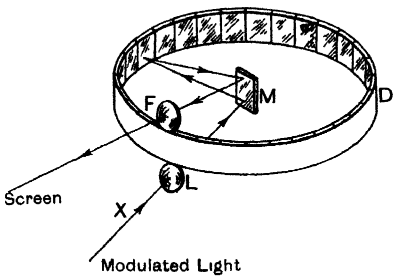


FIG. 125.

Recent improvements in the system involve the use of double-spiral mirror screws, curved surface screws, etc.

(5) THE MIHALY SYSTEM.—This uses, not a revolving, but a stationary mirror drum, and some idea of the principle will be gathered from Fig. 125. There is a stationary drum D on the *inside* of which is a number of mirrors, each being at a slight angle to the one preceding it, and at the centre of the drum is a small revolving mirror M (silvered on both sides). By means of a Kerr cell combination, the receiver output is caused to modulate the light from a projector lamp more or less in the usual way. This modulated light X passes through the lens L to the

rotating mirror M which reflects it and (since M is rotating) sweeps it over the tilted mirrors on the inside of the drum. These reflect it back on to the top of M from which it is again reflected through the large focusing lens F to the screen on which the picture is built up. Only the general idea is indicated in Fig. 125.

The Mihaly system has been considerably improved by E. H. Traub in what is known as the *Mihaly-Traub System* of the International Television Corporation.

5. Tele-Photography

Tele-photography—the transmission of photographs by wire and wireless—is now used by many of the leading newspapers, and as it is a related subject to television a brief reference may be made to it. Several systems are in use, *e.g.* the " Siemens-Karolus-Telefunken," the " Belin," the " Bell," etc. We will take the Bell system to illustrate the general principle.

At the sending end the photograph, prepared in the form of a transparency, is mounted on a cylinder which, while rotating, is, by a screw mechanism, moved slowly along in the direction of its axis. A light-spot, which has the same width as the thread of the screw is focused on the photographic transparency, and as a result of the two movements referred to, the whole picture is scanned in the form of fine, close, parallel strips. Clearly the amount of light transmitted through the picture (or in some systems the amount reflected from it) at any moment will depend on the density of the part of the picture being scanned at that moment. This varying light falls on the cathode of a photo-electric cell, and a varying current is produced which after amplification is passed to line or caused to modulate a carrier wave in the usual way.

At the receiving end the varying currents are amplified and then passed into what is called a " light valve." The light valve merely consists of a metal ribbon strung in a magnetic field due to a large " field coil." Light from a

lamp passes through a hole in the field coil and falls on the ribbon. By means of two movable jaws the size of this hole is so adjusted that when the ribbon is stationary it completely covers the opening so that no light can pass through to the other side.

Now when the incoming varying picture currents pass through, the ribbon vibrates, and in so doing it no longer blocks up the opening—some light passes through. The amount passing through varies with the vibration of the ribbon and therefore varies with the varying current received. In other words we get a light passing through which varies in proportion to the current from the photo-electric cell at the sending end and therefore in proportion to the light through the photograph being transmitted. The varying light from the light valve is finally focused on to a photographic film mounted on a cylinder which is rotating and advancing in synchronism with the photograph and cylinder at the sending end. Thus the photograph is reproduced.

We have put this explanation as briefly as possible, but you should be able to follow the principle from this and from the details of previous chapters.

CHAPTER VIII

THE B.B.C. FIRST HIGH DEFINITION TELEVISION STATION: MISCELLANEOUS

As already stated, the first high definition television station of the B.B.C. is housed at the Alexandra Palace, London, which is itself built on land 300 feet above sea-level. As mentioned (page 163), the carrier wave-length for vision is 6·6 metres and for sound 7·2 metres—a wave-length difference of only ·6 metre but a difference in frequency of about 3,800 kilocycles (see pages 83-93).

1. Two Standards at Work

The Television Advisory Committee recommended that for an "experimental period," two systems should be installed at the Palace, viz. that of the Baird Television Company and that of the Marconi E.M.I. Television Company, the systems to be used alternately. Again as explained in preceding pages, Baird's equipment uses 240-line ordinary or sequential scanning and 25 pictures per second, whilst the Marconi E.M.I. uses 405-line interlaced scanning and 25 pictures per second, the interlacing giving 50 frames per second with 202½ lines per frame (page 130).

This "trying out" under more or less like conditions of *two different television systems* which were running each other almost "neck to neck" in efficiency was, in some respects, all to the good of our television service, although it had its drawbacks in the sense that the two equipments reduced the space available for each, with the result that the studios were overcrowded when working—operators,

appliances, cable, everywhere: and rehearsals fitting in "as best they could." But the introduction of *two different standards* into the first public transmissions of the B.B.C. led to much adverse criticism which continued throughout the whole of the two-standard transmission period.

This adverse criticism came first and foremost from the manufacturers and intending manufacturers of television receivers, for the two standards naturally complicated and increased the cost of their models. Experience soon showed that although this increased complication was certainly there, it was not quite so serious (technically) as had been anticipated, and receivers (with C.R. tubes) to take *both* transmissions were quickly available: the cost of these, however, was somewhat of a drawback.

Again, apart from the space congestion due to the duplication of everything—transmitters, studios, controls, etc.—the different standards called for different technique, different types of " make up " for artists, etc., all of which further complicated the actual working and organisation of the station: it hampered the producers, artists, technicians, and operators alike. To further the progress of the first public television service from the Palace it became evident that *one standard,* at any rate, must be put into operation at the one station and at the earliest possible moment.

Theory indicates, as already explained, that the more the pictures per second, the better from the " absence of flicker " point of view; and the more the scanning lines, the greater the detail. (But many manufacturers would prefer this to be attained by sequential rather than by interlaced scanning if possible.) Judging from the experimental transmissions, the pictures seemed to be much the same on the two systems, especially when films were dealt with; and opinions seemed to vary in other cases, the bias being in favour of the greater number of scanning lines. But from the point of view only of "comparison of

results," the experimental period was none too long, and the programme material during the period none too varied in character (the B.B.C. was not solely to blame for this) for a detailed examination: moreover, it is not a simple matter to make a true comparison between two systems so close in efficiency unless the same transmission be sent out by both as near together as possible, and the resulting pictures be examined almost together, thus ensuring more or less identical conditions alike in subject-matter, transmission, and reception. After all, even the "personal equation" of a looker-in is not an absolute constant for all time.

However, the B.B.C. ultimately decided to use only the Marconi E.M.I. system for the first London station: but this does not mean that the Baird system may not be used in some of the stations still to be erected, and many manufacturers would even prefer to market two receivers, one for each system, rather than design one more complicated and costly, technically capable of receiving both. There is no doubt that each system has its merits, so much so in fact that despite the drawbacks as to space, etc., many would have welcomed the retention of both at the Palace, *but working on the same standard.* However, the tendency of television research both in this country and abroad is in the direction of higher definition, *i.e.* more lines. In America, Philco (with the iconoscope), Farnsworth (with the electron image dissector and multiplier), and others are working on 441: and theory alone would seem to indicate that any future forward steps in the direction of increased size of televised scenes and of received pictures will be associated with the use of increased number of scanning lines. As Baird and Marconi E.M.I. have both experimented up to over 700 lines, it should be possible for the two companies and the B.B.C. to arrive at some agreed high standard common to both so that both may play their well-merited part in Britain's television broadcasts.

To maintain the historical and logical sequence in this book of the progress of television in this country, we will briefly describe both the Baird and the Marconi E.M.I. equipments at the Palace.

2. Details of the H.D. Television Signals

At the outset both the Baird Co. and the Marconi E.M.I. Co. supplied technical details of their television *signals*, and although these were intended primarily for the manufacturers of television receivers, we give below remarks on a few of the points which will be of interest to readers of this book: these will be readily understood from what has been said in preceding pages.

(*a*) In both cases the " scanning " *as seen by an observer looking at the received picture from the front* is from left to right and from top to bottom. (Remember that " left to right " viewed from the front of the screen means " right to left " at the other side.) Baird's picture-ratio follows the custom of the cinema, viz. 4 : 3 (after allowing for synchronising pulses, etc.), as already explained. The E.M.I. differs slightly from this, being in fact 5 : 4. Baird's picture width is therefore 1·33 times its height, as at the theatre, and E.M.I.'s width is 1·25 times the height.

(*b*) The *total frequency band* in the Baird system is about 2,000 kilocycles, and the E.M.I. is about double this: this was shown in Chapter IV. Now the standard—the fidelity—of the picture we get depends, of course, on the capability of our receiving set to utilise the sidebands: this has been dealt with in previous pages. Hence if a manufacturer put a receiver on the market which could only cope with a *total* 2,000 kilocycle band width, justice could not be done to the E.M.I. picture, but the Baird picture would be up to standard: if the receiver accommodated the bigger band, both pictures would be up to standard. On the other hand, the E.M.I. definitely stated that " good pictures can be received utilising only a fraction of the radiated band."

(*c*) We have seen that synchronising pulses are sent out between each scanning line (high frequency synchronising pulses): this means there must be an interval between lines to provide time for the pulse and also time for the "fly-back" (page 150). In the Baird system the time devoted to these is 10 per cent. of the time of a line, of which 8 per cent. is pulse and 2 per cent. is "black" (page 146). In the E.M.I. the time is 15 per cent. of the time of a line, of which 10 per cent. is pulse and 5 per cent. is "black." Thus in the Baird system 90 per cent. of a line time is given to picture modulation, and in the E.M.I. 85 per cent. of a line time is given to picture modulation.

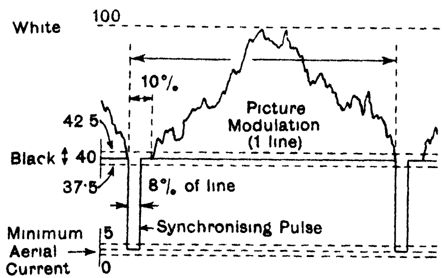


FIG 126 Baird—One line picture modulation and line synchronising (high frequency) pulse.

(*d*) It is interesting to compare the *actual times* taken up by a line synchronising pulse in the two systems. Baird's line time is $\frac{1}{6000}$ second, and 8 per cent. of this is $\frac{1}{75000}$ second. The E.M.I. line time is $\frac{1}{10125}$ second ($405 \times 25 = 10125$), and 10 per cent. of this is $\frac{1}{101250}$ second. The Baird pulse time is therefore about 1·3 times the E.M.I. pulse time.

(*e*) Again, as we have seen, there must be an interval between frames to provide time for the low frequency synchronising pulse and the fly-back. In Baird's system this is equal to the time taken for 20 lines (12 lines for pulse and 8 lines for "black"), and it occurs 25 times per second. In the E.M.I. the figure is 10 lines *per frame*, and it occurs 50 times per second (which means of course

20 lines *per picture* 25 times per second). Expressed by percentages as in (*c*) above these figures mean 8·3 per cent. cuts in the Baird system and about 5 per cent. in the E.M.I. system, leaving 91·7 per cent. and 95 per cent. respectively for picture modulation.

(*f*) The signal form of the transmissions of the Baird system is similar to those given in preceding pages (see, for example, Figs. 74, 88). Calling the maximum carrier strength 100 (say the highest peak of the curve in Fig. 88*c*), then from 100 (white) down to 40 (black—the dotted

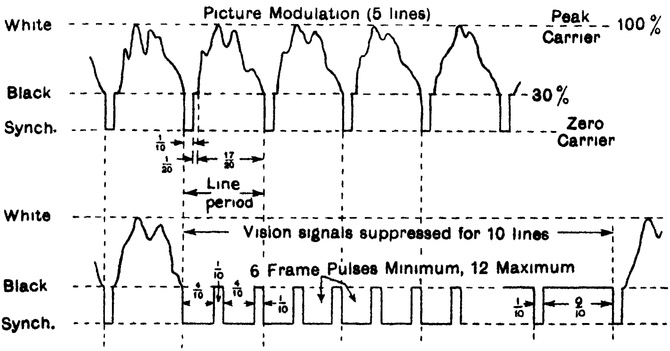


FIG. 127. Marconi E.M.I. ABOVE:—Five line signals. BELOW:—Signals at end of even frames.

line in Fig. 88*c*) covers the range for vision, *i.e.* for picture modulation: the remainder, *i.e.* from 40 down to zero, is used for fitting in the synchronising pulses. In the E.M.I. the picture modulation is in the limits 100 down to 30. Note particularly that in both cases the lower vision limit (black—dotted line in Fig. 88*c*) is a certain height above the zero carrier condition. Slight variations from the 40 per cent. (Baird) and 30 per cent. (E.M.I.) were allowable. The actual forms of the transmissions issued by the two companies are indicated in Figs. 126, 127, and many of the

preceding points will be gathered from the figures. Note the general similarity with what has previously been indicated in Figs. 74, 88.

(*g*) On page 132 we referred to the *average lighting* on a scene—a fire-light scene, a bright sunlit scene, etc.—as apart from the *light variations from different parts* of the objects televised. In both systems the average brightness is transmitted so that a definite carrier value is associated with a definite brightness: a scene strongly illuminated by the bright sun will increase the carrier value more than one illuminated by firelight. This can be made to affect the modulating arrangements of the receiver so that average brightness is indicated in the received picture. In the old television *average* lighting appeared the same for all pictures.

3. The General Arrangement at the Palace

The aerial mast is erected on one of the towers of the Palace, and reaches to a height of 300 feet above the ground—600 feet above sea-level (see pages 93-6). This steel mast is square in section for a height of about 100 feet above the tower, gradually decreasing from a square of 30 feet side at the bottom to one of 7 feet side at the top: the remainder of the mast is of uniform octagonal section, and fixed to it near the top are the two ultra-short wave aerials, the upper one being for vision and the lower one for sound.

The vision aerial consists of eight " dipoles " fixed vertically at equal distances round the mast: in addition there is another set of eight associated with, and fixed behind, the eight vision dipoles to act as reflectors. The sound aerial is similar in construction to the vision aerial and vertically below it. Two concentric feeders pass down the mast from these aerials to the vision and sound transmitters: a switching device was inserted so that either the Baird or the E.M.I. vision transmitter could be in the aerial circuit. Incidentally, there are transformers

(impedance matching transformers as they are termed) in the circuits between aerials and transmitters for "correction" purposes, but this is a detail we need not trouble about.

The transmitters are on the ground floor. There were three sets, viz. the Baird Vision Transmitter (45,000 kilocycles per second—wave-length 6·6 metres), the Marconi E.M.I. Vision Transmitter (45,000 kilocycles per second), and the B.B.C. Sound Transmitter (41,500 kilocycles per second—wave-length 7·2 metres).

On the first floor are situated the studios and scanning devices, control rooms, dressing rooms, offices, etc. The two large studios—one was for the Baird Co., the other for the E.M.I. Co.—are each about 70 feet long, 30 feet wide, and 26 feet high. The floors are dead black, and the walls are covered with an asbestos material which has good sound-absorbing properties. Several fixed and movable "microphone points" are installed, and arrangements are made for all "lighting" variations as required.

Amongst other features in the general lay-out of the television section of the Palace may be mentioned arrangements for moving the cameras, etc., outside the building for the television of out-door scenes and functions, space for scenery construction, fitting, and adaptation, a small cinema theatre for the "trying out" of films, etc.

4. The Baird Transmissions

The principles and methods of the Baird television have been explained on pages 97-124. As indicated, the Baird Co. have developed four main systems—

(*a*) The Spot-light system for close-ups—announcers, speakers, etc.—in the spot-light studio (page 97).

(*b*) The Intermediate Film system for all types of objects (or "subjects") and scenes in the large studio or for outdoor scenes (page 105).

(*c*) The Electron Camera system for all types of work in the large studio, for out-door work, and for films (page 109).

(*d*) The " Telecine " system for the transmission of films only (page 101).

The Company decided, however, to lead off at the Palace with (*a*), (*b*), and (*d*) only, and (*c*) was not installed until later.

(*a*) THE SPOT-LIGHT SYSTEM.—Little need be added to what has been already explained about this system. There was a small " spot-light studio " equipped with four (multiplier) photo-electric cells which communicated with what is called the A amplifier unit in the studio. Adjoining this was the projector room containing the scanning disc, etc., and the B amplifier unit, a window being fitted in the wall dividing the two compartments. In this system there are two discs running in a vacuous enclosure. One is the scanning disc with 240 holes arranged in 4 spirals, 60 holes per spiral, and it is driven by a motor (run in a vacuum) at 6,000 revolutions per minute. The other disc (driven by another motor) has a spiral slit near its edge, and is so rotated that it acts as the shutter device previously referred to (page 98): it ensures that only one hole is " active " at any one time. Synchronising pulses (end of each line) are generated, the " slits " for this purpose being arranged in a circle on the scanning disc as already explained (page 100).

The signals from the cells passed to the A amplifier, thence to the B amplifier, thence to a further output amplifier, and from here the picture signals (and amplified synchronising pulses) passed on to the control room, to which room the sound signals were also conducted.

(*b*) THE INTERMEDIATE FILM SYSTEM.—The principle of this has also been fully explained in preceding pages, and in its latest form with its numerous technical improvements and compactness in the arrangement of its parts it is an excellent mechanism.

The apparatus was located in a glass-fronted compartment of the large studio. The " developing tanks "

section of the device consists of an outer vessel containing warm water and fitted with *five* compartments for developing, washing, fixing, washing, and scanning (page 108). The photographic camera (intermittent) is situated above the developing tanks. The sensitive film (17·5 mm. film, *i.e.* half the normal 35 mm. film), driven by a motor, passes through the camera, then through a sound recording camera fixed immediately below it where a sound record is produced on the edge of the film, and then to the processing tanks and scanning compartment. By means of a pneumatic jack the system can be raised when necessary so that the film, etc., is clear of the tanks.

The method of scanning is that already explained in Chapter V. The scanning disc is in a vacuous enclosure. and so is its driving motor. The disc has 60 holes arranged *in a circle*, and its speed is 6,000 revolutions per minute: this means, of course, 4 revolutions (240 line journeys) in $\frac{1}{25}$ second, and during that time one picture image has passed. The varying light passing through the disc holes is focused on a multiplier photo-electric cell in what is termed the " head-amplifier unit " fixed above the scanning device. Synchronising pulses are produced in the usual way by means of 60 slits in the scanning disc, these pulses being fed to an amplifier unit below the scanning unit. After being scanned the film passes to a sound head above the scanning unit, and here (film in water) the sound record is converted into a corresponding varying current in the way already explained. Finally, the film is stored for future use by, say, the Telecine system.

The picture signals from the head amplifier of this appliance were dealt with in succession by an A amplifier, a B amplifier, and an output amplifier, and then passed to the control room, to which room the amplified synchronising pulses and sound signals were also passed.

Incidentally, when films are dealt with, one stage in an amplifying unit can be either in or out so that positive or negative films can be dealt with (page 108).

(*c*) THE ELECTRON CAMERA SYSTEM.—The principle of this system has also been dealt with in pages 109-124, and attention need only be drawn here to one or two special features in Baird's latest form of the device.

The " focusing coil " of the Dissector is similarly arranged to that of Fig. 87. Two deflecting or scanning coils carrying the two saw-tooth or scanning currents are also arranged round the dissector as in Fig. 87, but the disposition of these has been modified as indicated in Fig. 128, which is a section across the tube and in which $A.A_1$ and $B.B_1$ are the two pairs of deflecting coils. Special generators have been devised to produce the saw-tooth currents for the deflecting coils. These generators can produce saw-tooth currents of large amplitude and even up to 10,000 or more cycles frequency (remember the line frequency is 6,000 cycles for 240-line scanning 25 pictures per second), and send the signals along three or four hundred feet of cable with almost negligible departure from the " linear form " referred to on pages 113, 114, and again on page 152. Further, devices working somewhat on the principle of the cathode-ray tube (*cathode-ray oscillographs* as they are termed) are employed, which indicate *at once* any variation from the true linear saw tooth wave form or the correct frequency.

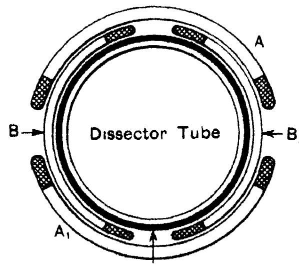
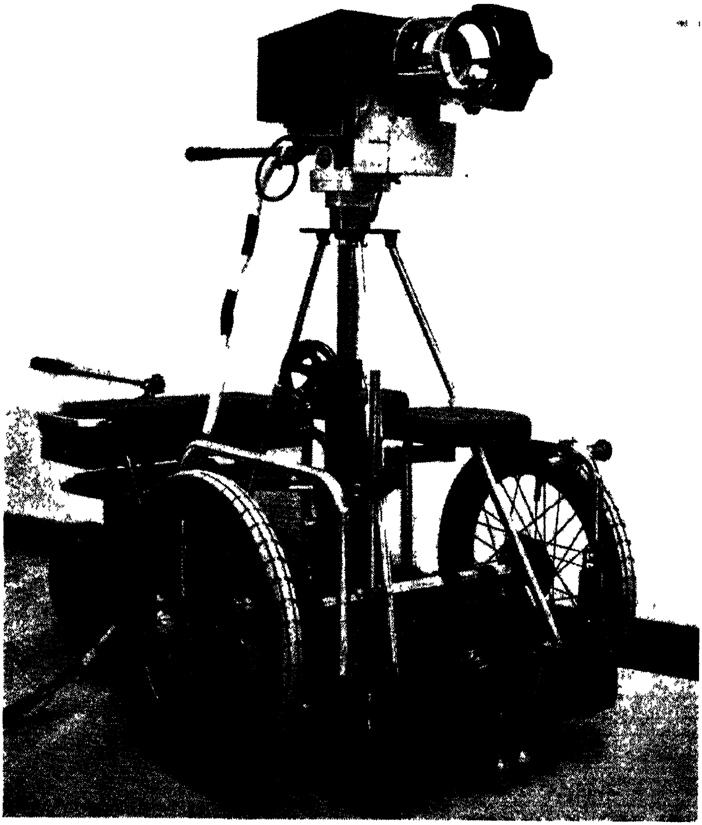


FIG. 128.

An electron multiplier is employed (page 121) to increase the signals from the dissector so that they are of sufficient strength to be further amplified by the usual valve amplifiers in the usual way. This is quite a small appliance which is fitted to the dissector, and it magnifies the dissector



Courtesy of Baird Television Co.

FIG. 129 The Baird Electron Camera on Studio Truck ready for use.

signals several hundred times: its general construction and action have already been explained.

The complete camera with focusing coil, deflecting coils, an amplifier referred to as the head amplier, and the whole containing cover, form an appliance no bigger than an ordinary film camera as used in film studios. Further, by the movement of a single control the focus can be changed so that when a scene is being televised any portion of the scene can be quickly magnified. Thus the received picture may be that of a group of persons in the distance which changes rapidly to that of the face of one of them occupying the entire screen—an effect often seen on the cinema screen: in the electron camera it is really brought about by altering the magnetic field in the dissector so as to alter the number of helical turns which the electrons make in travelling along the magnetic field (page 121).

At the Palace the camera was used for the television of scenes in the large studio. After the usual amplifications, etc., the picture signals, together with the amplified synchronising pulses and sound signals, were fed to the control room. The camera can, of course, be used for outdoor work even at long distances from the control equipment and transmitters, the connexion being by high frequency cable (or a radio link): this has already been referred to in preceding pages.

It should be noted that in the Intermediate Film system the sound is first recorded on the film and the film record is then used to produce the current variations constituting the sound signal which is fed to the control room. In the Camera system the sound signal is what we might call " direct pick up." In our opinion, based on the Palace broadcasts, the " sound " was better in the latter case than in the former (conversely, we considered the pictures from films were better than those from living persons and direct objects).

(*d*) THE TELECINE SYSTEM.—This is used for the television of ordinary commercial talking films (35 mm.), and has been fully dealt with in Chapter V. (pages 101-105).

The film is driven by a motor (1,500 r.p.m.) so that it passes steadily through the water-cooled gate at 25 pictures per second. From the gate is passes to the sound head situated below, and finally into the spool box where it is re-wound. The image is projected on the scanning disc, and picture signals and synchronising pulses are produced as already explained. The scanning disc, etc., is practically the same as is used in the Intermediate Film system. The picture signals were dealt with by A and B amplifiers, etc., and then, together with the amplified synchronising pulses and sound signals, they were fed to the control room.

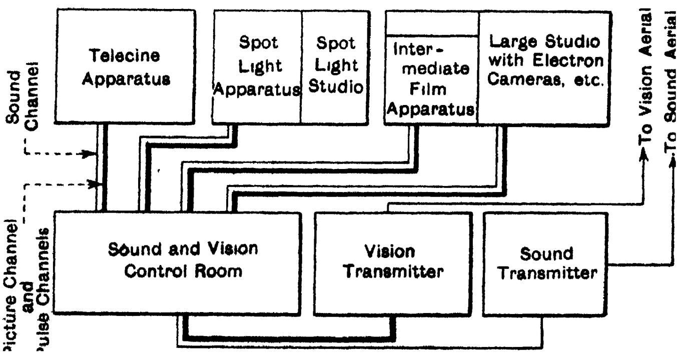


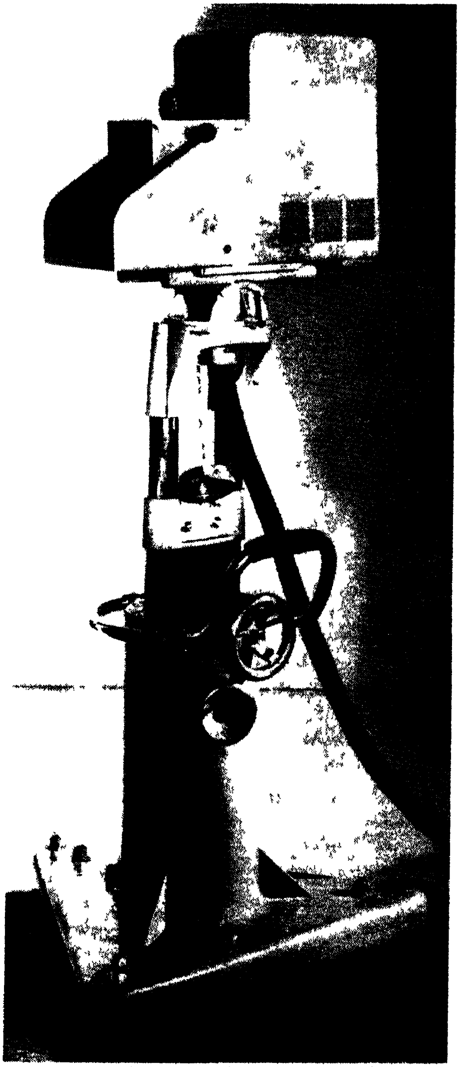
FIG. 130.

THE CONTROL ROOM.—We have seen that the control room was, as it were, the heart of the television installation. The technical equipment was of a complicated nature, the details of which belong more to the domain of electricity and wireless than to the scope of the subject-matter of this book: it contained checking, amplifying, and controlling apparatus for the vision, the pulses and the sound. The signals passed to terminating racks each with multiple amplifier units and ultimately modulated the vision and sound transmitters and hence the corresponding carrier waves.

A skeleton sketch of the Baird arrangement at the Palace is given in Fig 130 This does not indicate any technical details of the various units employed, nor does it show every stage of the process, but it will help to fix the general idea in the mind of the beginner

5 The Marconi E M I Transmissions

The *principle* of the method used by the Marconi E M I Company has also been dealt with in Chapter V (pages 125-132) Their system is that of the Iconoscope, the appliance in its latest form being known as the *Emitron Camera.* (Fig 131) As explained, these, like the electron cameras, are entirely electrical in operation, *i.e.* have no mechanically moving



Courtesy of the Marconi Wireless Telegraph Co.

FIG 131 The Marconi E M I "Emitron" Camera on Stand as used for Studio Work

parts. They are noiseless and absolutely immediate in their action, since the moving device is a narrow beam of cathode rays (electrons). The cameras are portable, can be used for indoor or outdoor work, or for films, and under all conditions of lighting—ordinary daylight or various grades of studio illumination. They can also be employed even at considerable distances from the transmitter, etc., connexion being by cable (or radio). In short, the iconoscope principle and the electron image camera principle are close-running rivals in the "all-electric" at the sending end in television.

It will be remembered (page 126) that an image of the scene to be televised is first focused on the sensitive plate in the camera so that we really have a multitude of tiny condensers each one of which is "charged" according to the light and shade of the part of the image falling on it. This image is then scanned by causing the narrow electron stream from the cathode at the narrow end of the tube to perform the usual horizontal and vertical saw-tooth motions over the surface, so that the tiny condensers are discharged in proper sequence, resulting in the corresponding picture signals in the signal plate. All this has, however, been fully explained. The picture signals are then passed to a "head amplifier" which is located in the camera: this amplifier is a four valve one, and it magnifies the signals sufficiently to enable them to pass through several feet of cable to the further amplifying and control units employed in the system. At the Palace, the E.M.I. Company's installation admits of the use of six cameras in the large studio, and the lay-out is such that any two may be in action so that a change-over from one to the other may be made without any break in the programme. Each camera has its operator (and assistants) who manages the positioning, focusing, etc., and all the cameras are controlled from an elevated room in the studio, in which room, in addition to control engineers, the producer is also at work.

As in the case of the Baird equipment, a full description and explanation of the various stages of amplification, control, etc., of the signals in their passage from the cameras through the installation to the transmitters and the aerials are technically complicated and beyond the scope of this book only a brief indication can be given.

Courtesy of the Marconi Wireless Telegraph Co

THE MARCONI E M I SYSTEM OF TELEVISION
Camera Scanning and Amplifying Rack on the right, Sound Amplifying Rack on the left, and Remote Control Desk in the centre

From the head amplifier in the camera the signals pass in succession to several racks containing correcting, amplifying, controlling, and mixing units. First comes the *unit for adjusting any defect in the illumination level,* and the *A amplifier.* From here the signals pass to what is termed the *phase changing unit:* like the corresponding unit in the Baird equipment this is merely to enable either positive or negative films to be dealt with at the camera. Following

this is the *mixer unit* under the control of the producer from his room: it enables him to separate out and pass on signals from any one camera or combination of cameras, *e.g.* it enables him to quickly change over from a distant scene by one camera to a close up by another if required. From here the signals pass to *further amplifying units* and apparatus for the elimination of interference, and then to the *unit for adding the synchronising pulses* in the correct positions to the picture signals: these pulses are produced by a special generator which also communicates with the cameras. The picture signals together with the synchronising pulses properly positioned now pass to *further amplifiers*, and then to *three modulator units*, each of several valves, which raise the power of the signals to pass on to the vision transmitter and thence to the vision aerial.

Several microphones in the studio pick up the sound, and the sound signals after amplification, etc., pass to the sound transmitter and thence to the sound aerial.

A skeleton sketch from which an idea of the arrangement will be gathered is given in Fig. 132. As in the case of the Baird system (Fig. 129) this does not give every stage nor the details of the stages, but it will help to fix the general scheme for a beginner.

As was pointed out on page 130 the image is on the plate of the Emitron camera all the time, so that each element builds up its charge again after the scanning beam leaves it, a fact which leads to some increase in signal strength from this type of appliance. It is often said in fact that the camera has a "memory" in the sense that if the camera lens be covered by its cap after exposure to a scene and then be left in this condition for some time it will, when switched into circuit again, transmit the scene which it was previously exposed to before being capped. Lookers-in to the Palace transmissions have on occasions noted some reading-matter on the sky of the interval signal (a picture of the Palace mast, etc.) which

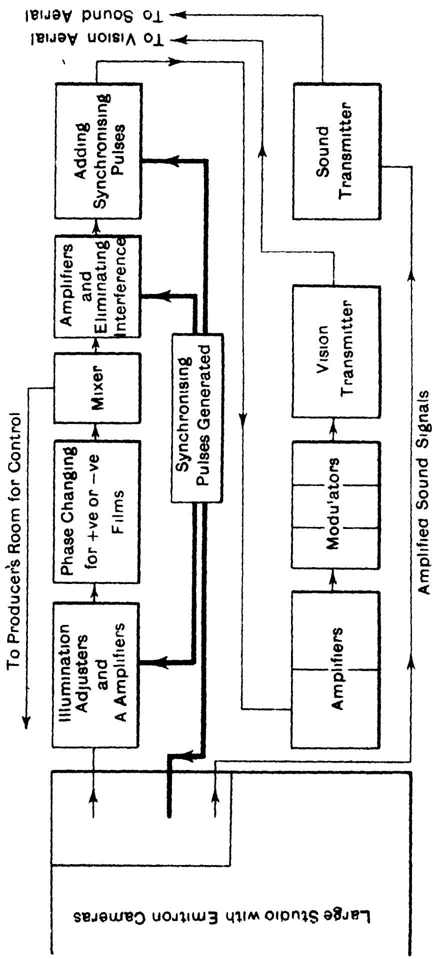


FIG 132

was really the wording of the previous transmission, the same camera having been used for both.

6. Just a few "Pointers" in Conclusion.

MECHANICAL-OPTICAL METHODS—AND THE LARGE SCREEN.—Decided progress has recently been made in the further development of at least two of the mechanical-optical systems referred to in Chapter VII., viz. the *Mihaly-Traub* and the *Scophony*, and particularly in the direction of "larger" screen reception.

The Mihaly-Traub latest apparatus follows the general underlying principle already given but, of course, with many improvements and extensions, the full details of which are not yet available. In place of the complete ring of fixed mirrors there is an arc of five mirrors set vertically, *i.e.* not inclined to each other, and a nine-sided polygon of glass with its faces silvered replaces the simple rotating mirror: this polygon rotates at 8,000 revolutions per minute (for 240-line), and associated with the device is a mirror drum (24 mirrors) rotating 60 times per minute. Instead of the usual Kerr or Grid cell a special cell specifically designed for the system is employed for light modulation. The received pictures are projected on the back of a ground-glass screen and are of the order $2\frac{1}{2}$ ft. × 2 ft. The Scophony system, too, has made considerable progress, but here again details of the progress are, naturally, still private: moreover, as already mentioned, the full principles apart from their application demand a knowledge of Physics beyond the scope of this book. It would seem, from various reports, to have a promising future for large screen work. Readers should "keep an eye" on the developments of these two systems.

Baird's latest large screen demonstrations held at the Dominion Theatre, London, resulted in an admirable picture 8 ft. × 6 ft. 6 in., and displayed a decided step forward in this type of work. The scanning system used is referred to as the *multi-mesh system*. Two scans each of 20 lines interlaced (40 lines) are given, and this 40-line group is repeated two more times, each group being so

shifted as to interlace with the others: thus the total scanning lines is 120. The scanning is brought about by the method of two moving systems based on the principles indicated in Chapter VII. (page 172), one being a disc with 12 slots revolving at 500 revolutions per minute, the other a mirror drum with 20 mirrors revolving at 6,000 revolutions per minute. The picture frequency is only $16\frac{2}{3}$ per second, but the novel method of scanning results in flicker being absent. At the receiving end a similar device is used for scanning, the light beam which does the scanning being obtained from an arc lamp and modulated by the receiver output being applied to a Kerr or other Grid cell (pages 67-73, 165). By using a different number of slots, etc., various combinations may be selected so that any number of scanning lines may be obtained with the device.

A NEW METHOD OF MODULATING IN C.R. TUBES.—A novel method of modulation of a C.R. tube has been patented by the Baird Co. Usually the signal output is applied to the cylinder or shield, thus varying the number of electrons in, and the intensity of, the electron stream according to the varying signal. In this new method the cathode is so constructed that its electron emission increases from a minimum at one end of it to a maximum at the other end. An electron image of the cathode is focused on a plate facing the cathode by means of a magnetic field, and the plate is provided with a central hole. Between the cathode and the plate is positioned a couple of deflecting plates joined to the receiver output. The output signal applied to these deflects the electron beam to and fro according to its strength, so that different parts of the cathode image fall at the hole and a different number of electrons pass through according to the intensity of the part of the image falling there. Thus the intensity of the electron stream varies in accordance with the received signal.

MAGNETIC FOCUSING IN C.R. TUBES.—In the C.R. tube we dealt with in preceding pages the focusing is done

electrostatically, i.e. by various anodes at different potentials (and so is the deflecting). There is on the market, however, a type where the focusing is done *magnetically, i.e.* by the magnetic field due to the current in a focusing coil just as in the case, for example, of the image dissector (page 117). The inside construction of the tube is simpler —a cathode, modulating cylinder, and one anode. The focusing coil is round the neck of the tube (outside) between the anode and the deflectors which also consist of coils carrying the necessary saw-tooth currents. This type of tube has certain points in its favour: altering picture brightness does not cause defocusing to any noticeable extent: if astigmatic effects occur, *e.g.* if the circular spot on the screen changes to the line or ellipse form, a slight angular movement of the coil will correct the defect: the construction is simpler (and cheaper) and the oscillators for scanning are also simpler (and cheaper). The tube has not been so much in favour as the electro-statically controlled one, and most makers concentrate on the latter. Recently, however, renewed interest has been taken in its possibilities. Baird's tube, however, is of this type, and Ferranti also makes one.

USING A RECEIVER.—We have said that a television receiver is not a difficult mechanism to handle, but many people who have not yet had the opportunity of using one still seem to imagine that it must be. In the early days of wireless the proud (and lucky) owner of a "powerful" multivalve set was regarded as a "bit of a genius" by the man in the street, for the set literally teemed with controlling knobs *all of which had to be manipulated by the operator.* The earlier television receivers also displayed several controls—a fact which led to the impression of difficulty in handling—but in practice only a few of these had to be handled by the user, the others being set once and for all by the engineers in constructing and in installing the receiver. In the latest types of receivers many of these

latter "controls" are placed in some inconspicuous position or more or less concealed from view.

It is impossible to explain fully by a specific example that the operation is *not* difficult, for a wordy explanation becomes more difficult than the actual "doing," and different makes of receivers differ somewhat in manipulation. In all sets there are in the first place *tuning controls* for sound and vision. In some sets these are "ganged," *i.e.* the tuning condensers are so combined that tuning in, say, the sound, also tunes in the vision: in others the sound is tuned in once for all by the engineer so that the user only has very slight changes to make in the vision tuner if such are necessary at any time to vary the detail and efficiency of the picture. Other controls are slightly different with different makers, but we may take the *latest* form of the Baird receiver in illustration. Here there are three outstanding controls marked *contrast, focus,* and *brightness.* The contrast knob alters the relationship between the tone of the light and dark parts of the picture according to the liking of the user: the focus control "sharpens" the picture: the brightness control alters the general or mean brightness level of the picture (a picture may be so bright as to weary the eye). Finally there are two controls for signal strength, viz. a *volume control* for sound just as there is in an ordinary wireless receiver, and a *vision control* which does the same for the vision signals. It will thus be seen that the operation of a receiver is not a highly skilled matter: moreover it will be clear that many of these controls once set can remain so for weeks on end and be given only slight adjustments on occasions as required.

Whilst the above are the typical controls to be used by the owner of the set, there are, of course, the time-base controls which have been adjusted by the makers or the engineer in installing and which are located in a less conspicuous position or hidden from view: these *can* be

manipulated by the user *if necessary* at any time to adjust picture steadiness, picture ratio, etc., but normally this is not required of the ordinary user.

As yet a further indication of the comparative simplicity of operation consider again the Cossor model (used for television) described on page 160. A careful examination of what was said there will reveal the fact that for many users, once the set has been installed and the knobs correctly set up, the manipulation to receive television will be little more than turning the selector switch to the television position, any further alteration of knobs (if necessary) being very slight.

THE RANGE OF ULTRA-SHORT WAVES.—We indicated on page 95 that the commonly accepted idea as to the maximum range of these waves (about 25 miles) was not correct, and that greater distances were indicated both by theory and by Baird's experimental work at the Crystal Palace. This has been confirmed by the television transmissions from the Alexandra Palace. The sound has been picked up even 100 miles from the Palace, and both sound and vision so far away as Brighton (55 miles): television receivers are in fact in regular use at Southend and on the south coast, and excellent reception from the Alexandra Palace is obtained. Of course, no definite statement as to range limit from the present station can yet be made, for some of the long distance records may be exceptional cases to which other circumstances also contribute. Further research is necessary, but it seems quite definite that the original anticipated distance is an under-estimate.

Incidentally there is just a point about *ordinary short wave* transmission—sound broadcasts, etc., on short waves —which is of special interest at present, and as it is a related subject to the preceding, brief reference may be made to it here. We have seen that wireless reception at great distances from a transmitting station is due to the sky waves which are reflected back to the earth by the Heaviside

layer, Appleton layer, etc., and that the actual effects of these layers varies with the wave-length and the time of day and night: it also varies with the seasons, and from year to year. Now in the case of short wave transmissions the reflections are mainly due to the Appleton layer (it is partly owing to the greater height of this layer that the short waves come down at a greater distance). This layer in particular seems to be altering its qualities from year to year, such alteration being associated with the variation in *sun-spots*. Sun-spots follow eleven-year cycles: there was a maximum sun-spot period in 1928, followed by a decrease to a minimum in 1933, and then an increase which will culminate in a maximum sun-spot period again in 1939. In unison with this cycle the reflecting layer is changing, and so is long-distance short wave transmission and reception. It has been predicted that short wave reception should improve with increasing sun-spot activity, but several factors affect the problem, and only experience and research will settle it. It is possible that our knowledge of short wave transmission—and perhaps our knowledge of the related problems, viz. *ultra*-short wave transmission and the range of the reception—will be considerably enlarged during the next few years.

THE QUESTION OF TELEVISION TERMS.—On page 82 we referred to the fact that, as in all new scientific developments, a little irregularity existed in the use of terms in television. The British Standards Institution have issued a book giving a Glossary of television terms which will do much to abolish confusion in the future. Scannings above 100 lines are to be referred to (as on page 80) as high definition. Picture frequency (again as on page 81) is to be taken as the number of *complete images* transmitted per second, and frame frequency as the number of scannings of the frame per second: in interlaced scanning the frame frequency is therefore always an integral *multiple* of the picture frequency. The very silly name "gun" as applied

in the C.R. tube is to disappear (page 139). It is recommended that the expression *time-base* should refer to the trace of the spot of light on the screen, which spot moves with a definite velocity for the purpose of imparting a time scale, and that the expression *time-base generator* should be applied to the *device for producing* a potential varying in a definite and periodic manner and used to impress on the electron beam of the tube a time scale deflection. Other terms are also quite definitely defined.

Television is now established as an important public service. As in the case of new advances in any science—and particularly electrical science, with all its ramifications, great and small—rapid extensions and developments are to be expected, and we hope that readers of this book will keep in touch with the progress. This can be done by the regular reading of suitable journals devoted to radio matters. Of these *Television and Short Wave World* can be strongly recommended for it is a really first-class journal, an excellent and reliable publication: moreover, most Wireless magazines regularly devote sections to television. Experimenters and students should also take an interest in the work of the Television Society, the Institute of Wireless Technology, and the Radio Society of Great Britain.

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PRINTED IN GREAT BRITAIN BY UNIVERSITY TUTORIAL PRESS LD., FOXTON NEAR CAMBRIDGE